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Volume III - EURATOM
Central Bureau for Nuclear Measurements - Geel
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PROGRESS REPORT ON NUCLEAR DATA RESEARCH IN THE EUROPEAN COMMUNITY

for the period January, 1 to December 31, 1974

Submitted by the Joint European Nuclear Data
and Reactor Physics Committee

(Secretariat: Central Bureau for Nuclear Measurements,
Euratom, Geel, Belgium)

February 1975

NUCLEAR ENERGY AGENCY NUCLEAR DATA COMMITTEE

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The figures in the left margin refer to request numbers listed in WRENDA 74 (April 1974) - INDC(SEC)-38/U

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EUROPEAN INSTITUTE FOR TRANSURANIUM ELEMENTS
KARLSRUHE

Fast fission yields and alpha-values of some nuclides 6[illegible]

1. FAST NEUTRON DATA

Abstract

Four experiments are in progress to measure some neutron data in the fast neutron region for fission reactor application. Of considerable interest is the case of the shape and average energy of the ^{239}Pu fission neutron spectrum where it is hoped that existing discrepancies will be resolved.

1.1. Data Evaluation for the Neutron Source Reaction ^{7}Li(p,n)

H. Liskien, A. Paulsen

Taking up a recommendation of the EANDC Symposium on Neutron Standards and Flux Normalization in 1970, center-of-mass best values for the normalized Legendre coefficients and the 0° differential cross sections as function of input energy have been derived from various experimental results for the reactions ^{7}Li(p,n)^{7}Be and ^{7}Li(p,n)^{7}Be*(431 keV) for proton energies bet[illegible] 7 MeV. This information has been used to calculate recommended laboratory differential cross sections as function of the laboratory proton energy and neutron emission angle. The work has been accepted for publication and will appear in Nuclear Data Tables Vol. 15 No. 1 January 1975.

1.2. Measurements of the Neutron Induced Fission Neutron Energy Spectrum of ^{239}Pu

H.-H. Knitter, M. Mailly, R. Vogt

592133 A good knowledge of the fission neutron [illegible] importance for neutronic calculations of fa[illegible] Previously, the spectrum of ^{235}U fission neutron[illegible] in this laboratory and this has been follow[illegible] ^{239}Pu fission neutron energy spectrum in[illegible] The fast neutron time-of-flight technique [illegible]

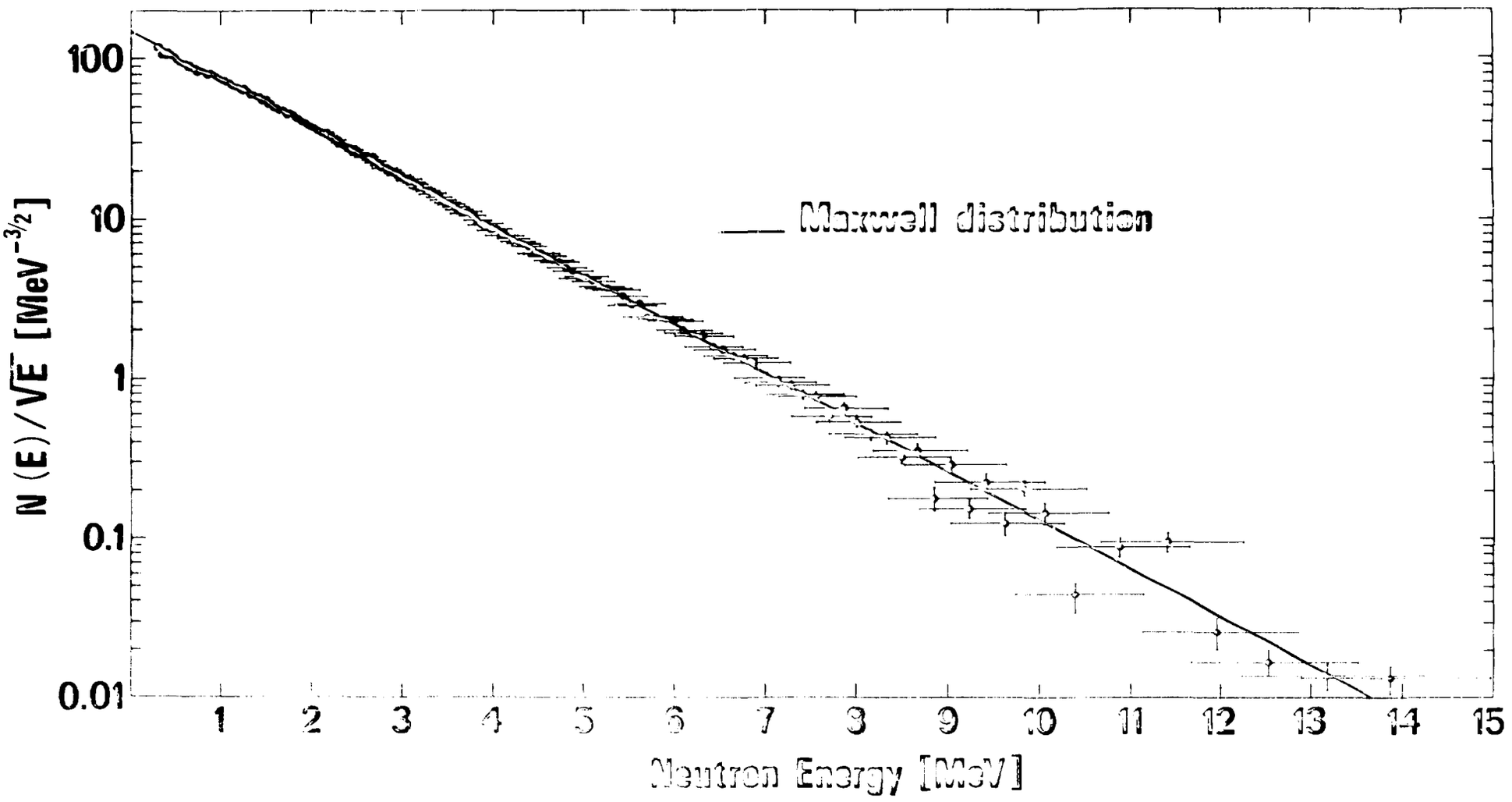
100
10
1
0.1
0.01
N (E) / √E [MeV^-3/2]
___ Maxwell distribution
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Neutron Energy [MeV]

Fig. 11

This measurement covers the fission neutron energy range from 0.25 to 15 MeV. Corrections for the shape of the spectrum have been made for secondary interactions of fission neutrons in the sample.

Figure 1.1 shows the fission neutron energy spectrum N(E) divided by the square root of the fission neutron energy plotted in a logarithmic scale versus the neutron energy.
The solid line represents the results of a least squares fit through the experimental data with a Maxwellian distribution. To obtain proper weights for the points in the least squares fit, the energy uncertainty was translated into an intensity uncertainty contribution. This translation was performed according to $\frac{dN}{N} = (\frac{1}{2} - \frac{E}{T}) \frac{dE}{E}$, a formula which is derived under the assumption that the experimental data follow a Maxwellian distribution with temperature T. The average energy obtained is 2.136 ± 0.045 MeV.
A paper about this subject is being written and will soon be published.

1.3. Determination of (n, 2n) Excitation Functions for ^{46}Ti, ^{66}Zn, ^{115}In and ^{197}Au

A. Paulsen, H. Liskien, [illegible] Widera, F. Arnotte

For actinide dosimetry purposes (n, 2n) excitation functions are being determined for ^{46}Ti, ^{66}Zn, ^{115}In (for the production of ^{114}In [illegible]) and ^{197}Au by the activation technique at the 3.7 MV Van de Graaff accelerator of the CBNM. All measurements were made relative to the H(n,n) cross-section by means of a recoil proton telescope counter
692315 in the 12 to 20 MeV neutron energy range making use of the T(d,n) neutron source reaction. For ^{197}Au (n, 2n) additional measurements were made between 10 and 12 MeV using the ^{15}N(p,n) source reaction. The induced activities were determined by calibrated Ge(Li) gamma detectors. Differences between the calibration sources and the actual samples in geometry and absorption were corrected for.
Irradiations and activity determinations are finished and final data evaluation is in progress.

The preliminary results are in reasonable agreement with existing data (mainly 14 MeV values) for ^{46}Ti and ^{66}Zn. For ^{115}In and ^{197}Au the preliminary results are confirming the lowest values of the existing data (again mainly 14 MeV values).

1.4. Measurements of the Fast Neutron Scattering and Total Cross Sections of ^{141}Pr and the Study of its Level Scheme by (n,n',γ) Measurements

R. Singh,[+] H.-H. Knitter, M. Mailly, R. Vogt

The level scheme of ^{141}Pr was studied by measuring the gamma ray spectra from the inelastic scattering of neutrons with energies between 1.10 and 2.22 MeV. In addition to the levels below 1651 keV, the levels 1785, 1813, 1842, 1856, 1975 and 2016 keV were confirmed and evidence was found for the existence of a previously proposed new level at 1899 keV.

A new transition 2103 ⟶ 1452 was added to the level scheme. No evidence was found in favour of the levels [illegible] 1946 keV and of the transitions 1651 ⟶ 1435, 1651 ⟶ 1[illegible] [illegible]7 ⟶ 0. The relative intensities and the branching ratios of the transitions were determined and compared with the previous results. Spins and parities of some of the levels were deduced. This part of the work has been published in Z. Physik 270, 97 (1974).

The differential elastic neutron scattering cross sections of ^{141}Pr were measured at the incident neutron energies of 1.2, 1.7 and 1.9 MeV in the angular range between 25 and 1[illegible] degrees. At 1.7 MeV the differential inelastic neutron scattering cross sections corresponding to Q = -1122 keV, and at 1.9 MeV the ones corresponding to Q = -1122, and Q = -1295 keV were also determined. In a transmission experiment, the total cross section was measured between 0.50 and 2.42 MeV. The total and differential elastic cross sections were calculated using the nuclear optical model and these were compared with the experimental data. This part of the work has been accepted for publication in Z. Physik.

[+] Department of Physics, Indian Institute of Technology, KANPUR, India

. RESONANCE NEUTRON DATA

Abstract

Measurements were continued at the Linac following the lines of a programme which emphasizes resonance parameter determination of actinides and which is guided by WRENDA request lists. A large part of that programme has been executed in collaboration with physicists of SCK/CEN-Mol. It was supplemented by the research activity of a team of CNEN-Bologna specialised on the investigation of neutron capture γ-ray spectra. This activity expired at the end of 1974 by the return of that team to Italy.

The extensive work on the resonance parameters of ^{236}U has been completed. Now ^{238}U is being investigated on a broad scale including capture, scattering, subthreshold fission and γ-ray spectra measurements. For the first half of 1975 also fission cross-section measurements on ^{241}Am and ^{239}Pu are envisaged.

Consideration is being given to the work programme with the modernised linac which is expected to be in operation April 1976. The short burst width of the machine should permit measurements in the keV to MeV range; and measurements on structural materials and fission products are being considered.

2.1. Resonance Parameters of ^{236}U

714011 Two sets of measurements have been completed, the first by Mewissen[+], Poortmans[+], Rohr, Theobald[++], Vanpraet[+++] and Weigmann. It is summarised as follows:

Capture, scattering and total cross-section measurements have been performed on ^{236}U, over an energy range from 30 eV up to 1.[illegible] keV, using the CBNM electron linac as a pulsed neutron source.

The total cross-section measurements were done on a small beam facility (beam diameter 11 mm) using a high pressure ^{3}He gaseous

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[+] SCK CEN Mol

[++] Now at Technische Hochschule Darmstadt, Fachbereich Physik

[+++] RUC Antwerp

scintillator at a 30 meter flightpath. The sample thickness was $n = 7.6 \times 10^{-3}$ atoms/barn (99.7% ^{236}U). The resonance parameters were obtained combining the results from an area analysis of the three experiments. The neutron width Γ_n could be determined for 97 levels up to 1.8 keV and the capture width Γ_γ for 57 among them.

The most important result from the present experiments is the mean capture width:

$$\bar{\Gamma}_\gamma = [23.0 \pm 0.5 \text{ (stat.)} \pm 1.0 \text{ (syst.)}]\text{meV}.$$

For the s-wave strength function we find:

$$S_o = (1.05 \pm 0.14)10^{-4}.$$

The second set of the measurements is by Brusegan and Carraro, the summary of which reads as follows:

The neutron total cross-section of ^{236}U has been measured by means of the time-of-flight technique at the 80 MeV Linac of CBNM using a ^{10}B plug detector at 100 m.

Neutron widths have been evaluated in the energy range from 40 eV up to 4.1 keV for 185 resonances. Sample thicknesses were $8.98 \cdot 10^{-3}$ atoms/barn and $1.34 \cdot 10^{-3}$ atoms/barn.

Assuming only s-wave contribution in the analysis range, the average properties of the resonance parameters have been determined as:

$$\bar{D} = (9.2 \pm .3)\text{eV}; \bar{\Gamma}_n^o = (1.61 \pm .16)\text{meV}; S_o = (1.00 \pm .10) \cdot 10^{-4}$$

The method of T. FUKETA and J. A. HARVEY was applied over the entire range to consider the missed resonances. The analysis of the level spacing and of the neutron width distribution has been performed applying respectively the WIGNER and the PORTER-THOMAS distribution. In order to look for possible p-wave resonances the method of BOLLINGER et al. and the Δ_3 DYSON statistic have been employed for all resonances. Besides the Dyson statistic has been applied to evaluate the expected mean level spacing $\bar{D}$.

3.2. Resonance Parameters of ^{238}U

L. Mewisser[+], F. Poortmans[+], G. Rohr, T. van der Veen,
G. Vanpraet[+++], H. Weigmann, J. Winter

Scattering Cross-Section Experiments have been done below 1.2 keV with 4 samples, respectively $1.312\ 10^{-5}$ at/b, $5.527\ 10^{-5}$ at/b, $1.004\ 10^{-3}$ at/b and $1.099\ 10^{-2}$ at/b. The measurements were performed on a 30 meter flightpath station using the ^{3}He high pressure gaseous scintillator detector system. The thinnest samples are 10 to 100 times thinner than those used in previous partial cross-section measurements in other laboratories so that possible errors on the corrections for multiple scattering effects are minimized. The total systematic error in our results is not larger than 3% and the statistical error is within 1% for strong resonances and 10% for weaker ones. The data are partly analysed for the two thinnest samples and preliminary results were communicated at the "Specialist Meeting on Resonance Parameters of Fertile Nuclei" held at Saclay, May 20-22, 1974.

A new series of transmission experiments with samples cooled at liquid nitrogen temperature will be started very soon.

Capture Cross-Section Experiments. A first run using a C_6F_6 γ-detector covering the neutron energy range from 20 eV to 1.8 keV and using a thick sample ($6.32 \cdot 10^{-2}$ at/b) is now analysed. The aim of this present analysis is twofold:

a) Determination of a precise value of the p-wave strength function by an area analysis of the smaller resonances in combination with resonance parity assignments (see b) and section 3.1.4.).

b) Information on the coupling conditions in sub-barrier fission of ^{238}U (see 3.10.) and resonance parities from the measured gross shape of the γ-ray spectrum.

Further capture cross-section experiments on thinner samples will be started soon.

2.3. Resonance Parameters of ^{237}Np

A. Angeletti *, L. Mewissen +, F. Poortmans +, G. Rohr,
T. van der Veen, G. Vanpraet +++, H. Weigmann

Transmission Experiments. The analysis is completed up to 50 eV for all three sample thicknesses: ($1.68 \cdot 10^{-3}$ g/cm^2, $5.23 \cdot 10^{-3}$ g/cm^2, $2.32 \cdot 10^{-2}$ g/cm^2). The data obtained with the 3 g sample ($5.23 \cdot 10^{-3}$ g/cm^2) yielded neutron widths for 128 resonances between 50 eV and 204 eV as a result of an area analysis. For some of these levels the analysis of the runs with other sample thicknesses will be necessary.

Scattering Experiments. The analysis of the scattering data (up to ~ 200 eV) is still in progress.

671114 Capture Experiments. Neutron widths for 110 resonances have now
671116 been evaluated up to 100 eV neutron energy.

Combined analysis of the results of total and partial cross section experiments will be performed after completion of the partial analysis to obtain the resonance parameter set.

2.4. Resonance Parameters of ^{226}Ra

H. Ceulemans +

Transmission experiments on a 1 g $RaCO_3$ sample with dimensions 14 mm x 5 mm by 6.5 mm high, have been conducted during a long period of time in order to obtain sufficient statistical accuracy. The source-sample distance is about 3 m and the detectors are at 30 m such that with timing channels of 40 ns minimum width and an initial delay of about 100 µs, the energy range between 10 and 600 eV can be covered with adequate resolution.
Due to the small size of the sample, the counting rates are very low.

+ SCK/CEN Mol

* Euratom-fellow

The sample can be rotated over 90° inside its heavy shielding so that it presents a thickness of either 14 mm or 5 mm to the beam, giving respectively 5.9×10^{-3} atoms/barn and 2.11×10^{-3} atoms/barn. Good statistical accuracy is very important in order to distinguish small resonances from fluctuations and to obtain in so doing a complete population of levels. In this work 19 resonances were firmly established. Their energy and an indication of their reduced neutron width are given in the table. The first resonance, which was measured before, is added for completeness (H. CEULEMANS, H. CHRISTIAEN, G. COEDEME, "The total cross-section of ^{226}Ra below 1 eV", Conference on Nuclear Structure Study with Neutrons, Budapest 1972, p. 100). These results lead to an average level distance $\langle D \rangle = 26.12$ eV which is a very reasonable value in agreement with the values found for the comparable neighbouring nuclei ^{232}Th and ^{238}U. The distribution of level spacings is not in disagreement with a Wigner distribution, but a detailed comparison is difficult due to the limited number of resonances. The same holds true for the distribution of reduced neutron widths. The analysis of the data is still in progress and a meaningful value for the strength function cannot be given yet.

Table of Resonances on ^{226}Ra

E_o (eV)	Γ_n^o (meV) (preliminary indication only)
[illegible]	0.029
24.23	0.002
39.12	0.01
39.73	0.06
55.47	0.3
80.45	0.01
88.16	0.5
[illegible]4.7	0.2
217.5	0.2
236.5	2.0
262.0	1.0

Table of Resonances on ^{226}Ra (continued)

E_o (eV)	Γ_n^o (meV) (preliminary indication only)
290.4	4.0
331.7	2.0
346.6	2.5
376.0	2.
396.7	3.0
460.4	0.5
470.9	0.4
481.7	0.2
522.3	1.5

691156

691164 2.5. Resonance Parameters of ^{91}Zr and ^{96}Zr

A. Brusegan, G. Rohr, T. van der Veen

Capture and self-indication data have been obtained with an enriched ^{91}Zr sample in the energy range from 150 eV to 20 keV using a pair of C_6F_6 detectors at a 62 m flightpath. Capture measurements on ^{96}Zr will be attempted in 1975.

When completed it is hoped to combine these data with the transmission data obtained by the CNEN group to evaluate resonance parameters.

2.6. Resonance Parameters of Nb

L. Mewissen+, F. Poortmans+, G. Rohr, T. van der Veen, H. Weigmann, J. Winter

Low Energy Capture γ-Ray Spectra have been measured vs time-of-flight up to 3 keV neutron energy at a 14 m flightpath with a Ge(Li)-detector. This experiment aims at the determination of resonance spins. The data acquisition system consists of a General Automation 1830 satellite computer linked with the IBM 1800

of CBNM (F. COLLING, A. DE KEYSER and H. HORSTMANN, Proc. of IFIP, Congress 1971).

In a preliminary analysis spins of 50 s- and p-wave resonances have been evaluated by means of the low level population method. (K.S. WETZEL and G.E. THOMAS, Phys. Rev. C1 (1970), 1501 and W.P. POENITZ, Z. Physik 197 (1966), 262.).

The 21 safe spin assignments reported by the Harwell group (T.J. HASTE and B.W. THOMAS, Sec. Int. Symp. on Neutron Capture Gamma Ray Spectroscopy Petten, Sept. 2-6, 1974) agree completely with the CBNM results but there may be disagreement for the resonances at 672 eV and 952.7 eV for which only tentative assignments were made by Harwell.

Scattering Cross-Section Measurements below 4 keV have been started by means of the high pressure ^{3}He scintillation detection system.
Transmission and capture experiments are planned for the near future.

2.7. Resonance Parameters of ^{240}Pu

69139, 714028

J. Poortmans[+], G. Rohr, H. Weigmann

An evaluation of the resonance parameters of ^{240}Pu has been presented at the "Specialist Meeting on Resonance Parameters of Fertile Nuclei and [illegible] at Saclay, May 20-22, 1974. It includes a review of the status of experimental data on ^{240}Pu resonance parameters as well as some statistical tests and recommendations particularly with respect to average parameters.

2.8. Gamma Ray Spectra of ^{143}Nd

G. Rohr, T. van der Veen, H. Weigmann, J. Winter

The γ-ray spectra measurements of ^{143}Nd in resolved resonances up to 1220 eV neutron energy, has been finished.
The resonance spin values obtained from the low level population method as well as from the observation of primary transition to 2^+ final levels and the strength of primary transitions to one and two

phonon final states for $J = 3^-$ resonances has been published. (G. ROHR, T. VAN DER VEEN, H. WEIGMANN, J. WINTER, Sec. Int. Symp. on Neutron Capture Gamma Ray Spectroscopy, Petten, Sept. 2-6, 1974). The results indicate an energy dependence for the anti-correlation between strengths of primary transitions to one and two phonon final states. The effect is supported by an observed non-statistical energy dependence of the reduced neutron width for the $J = 3^-$ resonances in the same energy range. A more detailed statistical analysis of the Γ_n^o distribution and a discussion of both phenomena in terms of intermediate structure will be published elsewhere.

Table 2.1 surveys all primary transitions observed in the resonances under investigation.

2.9. Fission of ^{235}U at High Energies

E. Migneco**, J. A. Wartena, H. Weigmann

661043 et al. on page 68 of WRENDA list.

A high resolution (0.7 nsec m) relative measurement of ^{235}U fission for energies up to 200 keV is being analysed for non-statistical structure. **Figure 2.1** shows part of the data which have been normalized to the evaluation of SOWERBY et al. (AERE-R 7273).

The analysis includes Wald and Wolfowitz-tests for structure in the fission data in comparison to similar data on the total cross section. (K. H. BOECKHOFF, A. DUFRASNE, G. ROHR and H. WEIGMANN, Journ. Nucl. Energy 26 (1972) 91). It yields positive results for structures in the fission cross-section which might be interpreted in terms of the secondary minimum of the deformation potential.

2.10. Sub-Barrier Fission of ^{238}U

J. A. Wartena, H. Weigmann

Sub-barrier fission in ^{238}U has first been observed by R. BLOCK et al (Phys. Rev. Lett. 31 (1973) 247), using ionization chambers for fission fragment detection. In the present measurements a liquid scintillator was used to detect prompt fission neutrons. Thereby, with a sample

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** Now University of Catania (Italy)

Table 2.1 ^{145}Nd(n,γ) Transition intensities in transitions per 1000 capture events

Transit. No.	E_{res} (eV)		55(4⁻)	127(3⁻)	135(3⁻)	159(4⁻)	179(3⁻)	185(4⁻)	306(4⁻)	324(3⁻)	337(4⁻)	350(3⁻)	401(4⁻)	407(3⁻)	446(4⁻)
	E_γ (MeV)	E_x (MeV)													
1	7.12	0.696		< 1.6	13.8±1.1		44.8±1.6			17.5±2.5		11.0±3.0		16.7±2.2	
2	6.50	1.31		16.5±1.2	1.5±1.2		2.6±1.1			< 2.3	30±9	56.4±4.0	40±4	26.3±2.5	15.1±3
3	6.31	1.51	2.2±0.4												
4	6.26	1.56		87 ±1.7	34.2±1.7		6.7±1.3			3.1±2.7		27.4±4		< 2.4	
(5)	(5.77)	(2.04)				36.1±2.6)									
6	5.75	2.07			14 ±4.2		5.0±5.0								
7	5.63	2.18	4.2±1	10.7±2.6		14±4			25±10						
8	5.52	2.29	4.9±1.0												23 ±6
9	5.40	2.42	20 ±0.9					9.1±3.2							
10	5.37	2.45	18.5±1.0											22 ±5	
11	5.29	2.53			30.2±3.1		19.7±2.3			12.7±6.		16.5±6			
12	5.16	2.65	10.6±1.0									14 ±5.5			
13	5.12	2.69		7.7±2.6											
14	4.98	2.83		29 ±2.4			11.0±3.2								
15	4.92	2.90		15 ±2.4											
16	4.87	2.95	15.6±1.3	6.8±2.5											
17	[illegible]	3.02		12 ±4											
18	[illegible]	[illegible]	5.7±1.2												
19	[illegible]	[illegible]		4.5±2.5						-					
[illegible]	[illegible]	[illegible]	2.0±1.2												

Fig 2.1 Trace of high spectrum from ^{235}U (n,f)

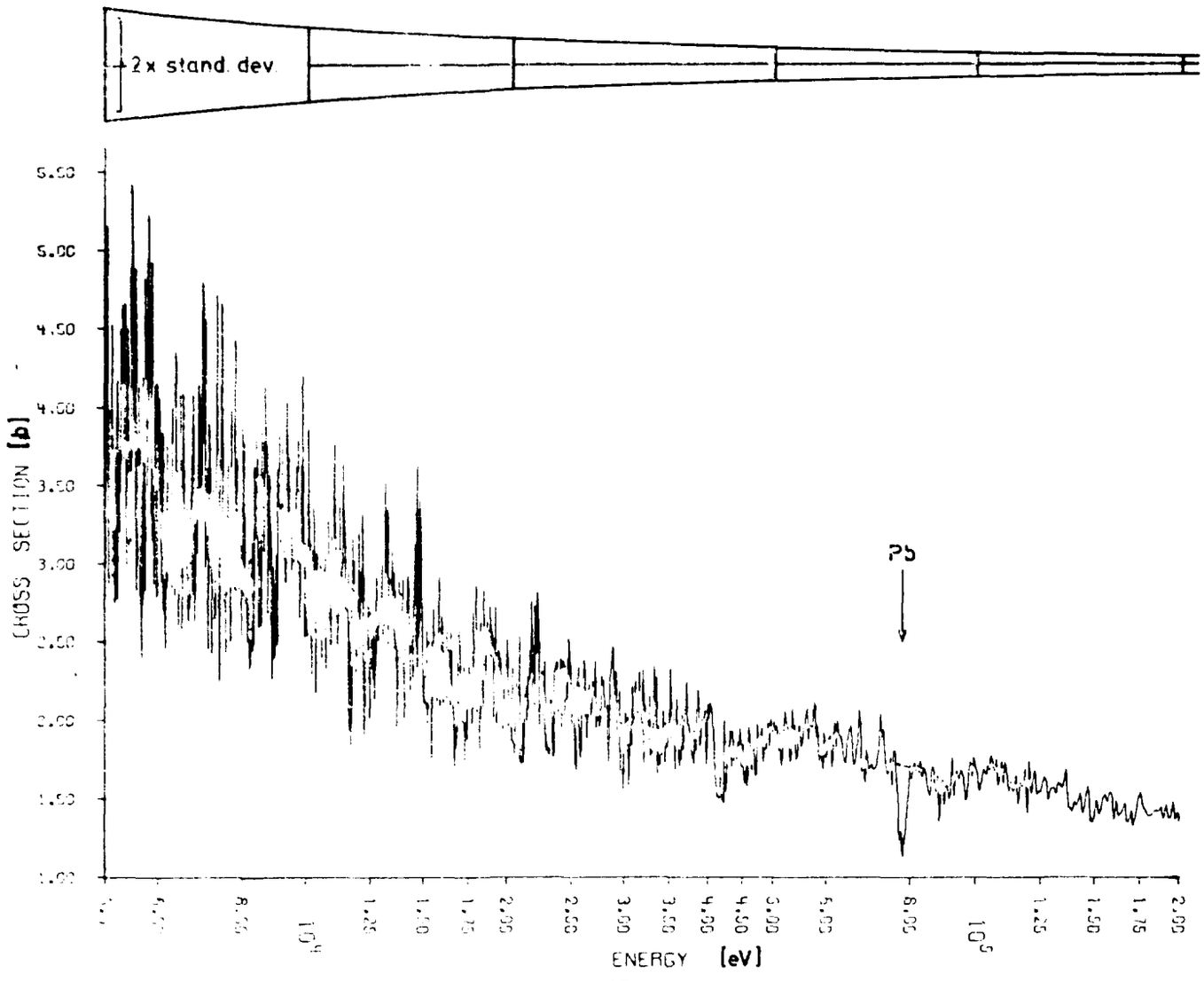

Fig 2 2 Relative fission cross section of ^{235}U.

of 250 g of ^{238}U, neutron time-of-flight measurements could be performed at a 30 m flightpath with a nominal resolution of 1.3 nsec/m. On the other hand, prompt neutron detection has the disadvantage that the detector has a sensitivity for capture events of 10^{-3} of its fission sensitivity. The corresponding background has been measured separately by taking a time-of-flight spectrum under conditions identical to the main run, but with the pulse shape discriminators of the detectors set to detect capture. Another source of background is fission in 0.2% of ^{235}U present in the sample. Again, this background has been measured separately with a ^{235}U sample in the beam.

Figure 2.2 shows a time-of-flight spectrum of fission in ^{238}U as obtained from the present data, where the two background contributions discussed above have already been subtracted. The result of the present investigation is a full confirmation of the findings of BLOCK et al. (Phys.Rev. Lett. 31 (1973) 247). This includes a confirmation, by high resolution data, of the fact that the resonances at 721.0 eV and 1210.7 eV contribute most strongly to the observed fission in the two sub-barrier structures at low neutron energies. Their fission widths are found to be (0.85 ± 0.13)meV and (0.26 ± 0.05) meV, respectively (assuming Γ_γ = 23 meV). For most of the other resonances in these two structures only upper limits for the fission widths are obtained. Also in agreement with the data of BLOCK et al., besides the two structures around 720 and 1210 eV, some fission is observed around 220 eV and 860 eV neutron energy. However, from the present data it is not possible to assign the resonances which are responsible for the fission strength at these energies.

2.11 Coupling Conditions in Sub-Barrier Fission of ^{237}Np and ^{238}U

G. Rohr, T. van der Veen, G. Vanpraet[+++], H. Weigmann

Neutron resonance capture in ^{237}Np and ^{238}U has been studied at resonances which show enhanced fission due to coupling to states associated with the secondary minimum of the deformation energy. No anomality has been found in the gross shape of the γ-ray spectra from these resonances. From this fact, conclusions are drawn with respect to the coupling conditions in sub-barrier fission and these

have been discussed in more detail elsewhere (H. WEIGMANN, G. ROHR, T. VAN DER VEEN, G. VANPRAET, Sec. Int. Symp. on Neutron Capture Gamma Ray Spectroscopy, Petten, Sept. 2-6, 1974).

2.12. Fission Fragment Kinetic Energy and Mass Distribution for ^{235}U.

R. Barthélémy, C. Wagemans***, H. Weigmann

A three parameter data acquisition system has been built up based on a Tridac (Intertechnique) 16K memory system, two Northern Scientific 8K ADC's and a home made time-coder. For the fission fragment detection two large (2000 mm^2) Ortec surface-barrier detectors with their appropriate electronics were used. This apparatus allows the detection of correlated fission fragment pulse-heights (E_1, E_2) in a 128 x 128 channels matrix, and this for four predetermined neutron energy intervals.

The aim of the present experiment is to investigate the fission fragment kinetic energy- and mass-distributions for the resonance neutron induced fission of ^{235}U. Reliable resonance spin values (J) are available for this isotope and hence it will be possible to look for correlations of J with E_K (mean total fission fragment kinetic energy) and the symmetric-to-asymmetric fission yield.

In the recently started measurements E_1 and E_2 were detected for four predetermined groups of J = 4 resonances: 7 - 12 eV; 15 - 17 eV; 19 - 21 eV; 31 - 35 eV. Similar measurements will be performed for four J = 3 resonances.

*** NFWO, Rijksuniversiteit Gent and SCK-Mol

2.13. Direct α-Determination of ^{235}U from the Measurement of low-energy γ-rays

F. Corvi*, and P. Giacobbe**

691249 A new method has been applied for the determination of α of ^{235}U.
691252 In conventional measurements of capture-to-fission ratios, expe-
692373 rimental data usually need to be corrected for fission contamination
714008 in the capture counting rates. This correction considerably contri-
721077 butes to the systematic errors present in the final data.

To overcome such a difficulty, the new technique of α determination consists of measuring with a Ge(Li)-detector low-energy γ-ray spectra emitted from ^{235}U, as a function of neutron energy. Complete discrimination between capture and fission events is thus achieved by the amplitude analysis. It can be shown that a relative value of α can then be deduced assuming that the intensity of a given capture (fission) γ-ray is proportional to the average capture (fission) cross-section. More specifically, α is taken proportional to the ratio between the intensity of the 642 keV capture transition and the sum of the intensities of the fission γ-rays at 352 keV and 1280 keV. Average α values with statistical errors less or equal to $\pm$ 5% were determined for 19 intervals covering the neutron energy range 15 eV - 30 keV.

2.14. p-wave Assignment of ^{238}U Neutron Resonances

F. Corvi*

In an effort to perform p-wave assignment of ^{238}U neutron resonances the fraction of capture γ rays above 4.3 MeV was measured with two 7" x 6" NaI(Tl) detectors in the range 10 - 2500 eV. Since the selected transitions end at levels of positive parity only, they will be M1 for s-wave and E1 for p-wave resonances; their enhancement can then be used as an indication of p-wave levels. However, the method is not 100% ef-

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* CNEN, Bologna. Since 1st September staff member of CBNM-Geel

** CNEN, Bologna

fective due to PORTER-THOMAS fluctuations of the few transition widths available, which make the E1 and M1 intensity distributions partly overlap.

The measurements are being performed at a 50 m flightpath: one run with a $3.50 \cdot 10^{-2}$ at/barn thick sample was completed at the end of July and the data are being analysed. A second run on a $1.17 \cdot 10^{-2}$ at/barn sample is in progress. A preliminary analysis of the first run shows that more than 60 p-wave resonances can be selected in the range 10 - 1800 eV. These assignments will be used in conjunction with the capture data of section 2.2. to derive estimates of the p-wave strength function and of the average s-wave level spacing D_o.

2.15. Measurement of the Relative Contribution of Different Spins to the Neutron Capture Cross-Section.

C. Coceva**, P. Giacobbe**

A method was devised (C. COCEVA, 2nd International School on Neutron Physics, Alushta, USSR, April 2-19, 1974 - Dubna D3-7991, pag. 266 - 293) for the experimental determination of the relative contribution of resonances with different spins to the total capture rate in energy intervals containing several resonances. Under certain conditions the strength-function ratio of the two spin states of s-wave resonances in an odd target nucleus can be deduced from the measurement. Such a method has the advantage of being applicable in energy regions where the resonances are unresolved, i.e. where the usual procedure of assigning the spins and measuring the parameters resonance by resonance cannot be applied. The method is based on intensity measurements of particular low-energy γ-rays of the capture cascade. As an application, capture γ-ray spectra of ^{165}Ho were measured in single resonances up to 400 eV and in energy intervals including many unresolved resonances from 400 eV to 2 keV. In the resolved region, the spins of the resonances were assigned and the results of the method were checked with the help of known resonance parameters. Fluctuations are observed in the relative contributions of J = 3 and J = 4 to the capture cross-section.

2.16. Spin Assignment of Bound Levels Populated by (n, γ) Reactions

C. Coceva**, P. Giacobbe**

Capture-γ-spectra have been measured with natural samples at the resonances of the isotopes ^{99,101}Ru and ^{191,193}Ir in the resp. γ-energy ranges 390 - 1900 keV and 120 - 600 keV. The measurement aims at deducing the spins of low-lying levels from a comparison of their populations for resonances with different spins (C. COCEVA, P. GIACOBBE, F. CORVI and M. STEFANON, Nucl. Phys. A 218 (1974) 61-83). Data evaluation will begin in 1975.

2.17. Primary γ-ray Spectra from Capture in ^{133}Cs Resonances

C. Coceva**, M. Stefanon**

Gamma rays in the range 5 - 7 MeV have been measured for 30 resonances of ^{133}Cs, selected by time-of-flight in the range 5 - 900 eV. The objects of the measurement are the estimation of average values and fluctuations of the reduced E1 and M1 radiative widths, and the determination of spin and parity of low-lying states of ^{134}Cs.
A subsidiary measurement was performed in order to assign the spins of ^{133}Cs neutron resonances: time-of-flight spectra were measured of the γ-rays de-exciting the (3^-) metastable state at $E_{ex} \simeq 176$ keV. Such γ-rays were detected with a NaI(Tl) crystal and selected by taking advantage of their decay ($T_{1/2} \simeq 50$ nsec) with respect to the corresponding capture events. Data evaluation will begin in 1975.

2.18. Gamma Rays from Resonance Neutron Capture in ^{115}In

F. Corvi*, M. Stefanon**

This work was published (F. CORVI and M. STEFANON, Nucl. Phys. A 233 (1974) 185) with the following abstract:

Gamma rays in the range 5.4 - 6.7 MeV have been studied for 31 s-wave neutron resonances of ^{115}In, selected by time-of-flight in the range 3 - 430 eV. In a subsidiary experiment, spin J = 5 has been assigned to 17 and J = 4 to 14 resonances by measuring intensity variations of some strong low-energy transitions. The reduced widths averaged over all initial states of the same spin have been estimated for 41 primary transitions: these values have provided information on the spin and parity of the corresponding ^{116}In final states. Overall mean values of E1 and M1 radiative strengths have been calculated. The width distribution has been fitted with a χ^2 function with $\nu = 1.10^{+0.27}_{-0.09}$ degrees of freedom for M1 and $\nu = 1.42^{+0.14}_{-0.08}$ for E1 radiation. An estimate of the spin cut-off parameter $\sigma = 3.6^{+0.8}_{-0.4}$ has been derived. A non-statistical effect already evidenced in previous measurements has been confirmed, consisting of a strong modulation of the radiative strength against resonance energy, correlated also with the local neutron strength function. In addition, it has now been shown that this structure is due to E1 radiation only.

2.19. Montecarlo Calculations for the Moderator at a Linac Target

A. Bignami**, C. Coceva**, R. Simonini**

This work was published (A. BIGNAMI, C. COCEVA and R. SIMONINI, EUR. 5157. e (1974)) with the following abstract:

The results are reported of montecarlo calculations which were performed to compare the characteristics of two different dispositions of the moderator near the pulsed neutron target of the Geel linear accelerator for neutron time-of-flight experiments. The resolution function is obtained for the disposition eventually chosen. The effect of different flightpath directions on the resolution is evaluated.

3. STANDARD NEUTRON CROSS SECTION DATA

Abstract

The programme on standard neutron cross-section data deals with the measurement of the cross-section types $\sigma_{n,\alpha}$, σ_{tot}, $\sigma_{n,\gamma}$, σ_f and with the calibration of fast neutron fluence monitors. The neutron measurements are performed at the Van de Graaff, the electron linear accelerator and the slow chopper facility of the SCK's BR-2 reactor (Studiecentrum voor Kernenergie, Mol).

Measurements pertaining to the ^{6}Li(n,α) cross-section are reviewed in section 3.1.. The evaluation of total cross-section measurements on ^{6}Li, H and C is started, the evaluation of elastic scattering cross-section measurements of ^{6}Li is in progress and a detector for (n, α) cross-section ratio measurements of ^{6}Li to ^{10}B is in the test phase. Preliminary results of ^{197}Au(n, gamma) cross-section data are discussed in section 3.2.. Final results on absolute fission cross-section data of ^{241}Pu in the energy range from 0.01 eV to 50 eV are reported in section 3.3. as well as preliminary fission cross-section data of ^{235}U up to 30 keV. The running experiment on fission of ^{233}U in the thermal energy range is briefly described in section 3.3.. The CBNM contribution to the international intercomparison of [illegible] neutron fluence detectors is given in section [illegible].

3.1. Measurements Pertaining to the ^{6}Li(n,α) Cross-Section

601099 et al on page 2 of WPENDA list

Total Neutron Cross Section Measurements on ^{6}Li, ^{7}Li, Carbon and Hydrogen between [illegible] and 2 MeV.

K. H. Böckhoff, A. Dufrasne

An experiment has been carried out at the Linac with the objective of obtaining an accurate value of the total cross-section of ^{6}Li in an energy range comprising the resonance near 250 keV. The experiment consisted of simultaneous transmission measurements on ^{6}Li, ^{7}Li and carbon samples. The measured cross-section data on ^{7}Li were used to correct for the ^{7}Li contribution of the enriched ^{6}Li samples. The data on carbon served to control the validity of the ^{6}Li and ^{7}Li data. Finally the validity of the carbon data were checked by means of a determination of the total cross-section of hydrogen re-

sulting from a simultaneous transmission measurement on a hexane (C_6H_{14}) and a carbon sample. In total three ^{6}Li, three ^{7}Li, two hexane and two carbon samples have been made. Data evaluation is in progress.

Transmission Measurements on ^{6}Li with the Monoenergetic Beam Technique between 0.1 - 2.4 MeV.

H. -H. Knitter, M. Mailly

Total cross-section measurements have been performed also in the energy range 0.1 to 2.4 MeV on ^{6}Li using the Van de Graaff. Corrections for the inscattering effect and the isotopic content of ^{7}Li in the sample were calculated and applied to the raw data. The total cross-section values are plotted in figure 3.1 versus the incident neutron energy. A preliminary representation of the total cross-section in terms of R-matrix theory was made. From the obtained parameters also the n-α cross-section was calculated. The value at its maximum in the prominent $5/2^-$ resonance came out to be higher than the frequently accepted value of 3.0 b. The analysis will be finalised, when the elastic neutron scattering data described below are available.

Differential Neutron Scattering Cross-Section Measurements on ^{6}Li between 0.25 and 3.0 MeV

H. -H. Knitter, R. Vogt

The measurements of the neutron differential elastic scattering cross-sections of ^{6}Li have been started at the Van de Graaff accelerator. Angular distributions at incident neutron energies of 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90 and 0.95 MeV have been measured but not yet evaluated. An attempt will be made to continue these measurements down to 0.25 MeV.

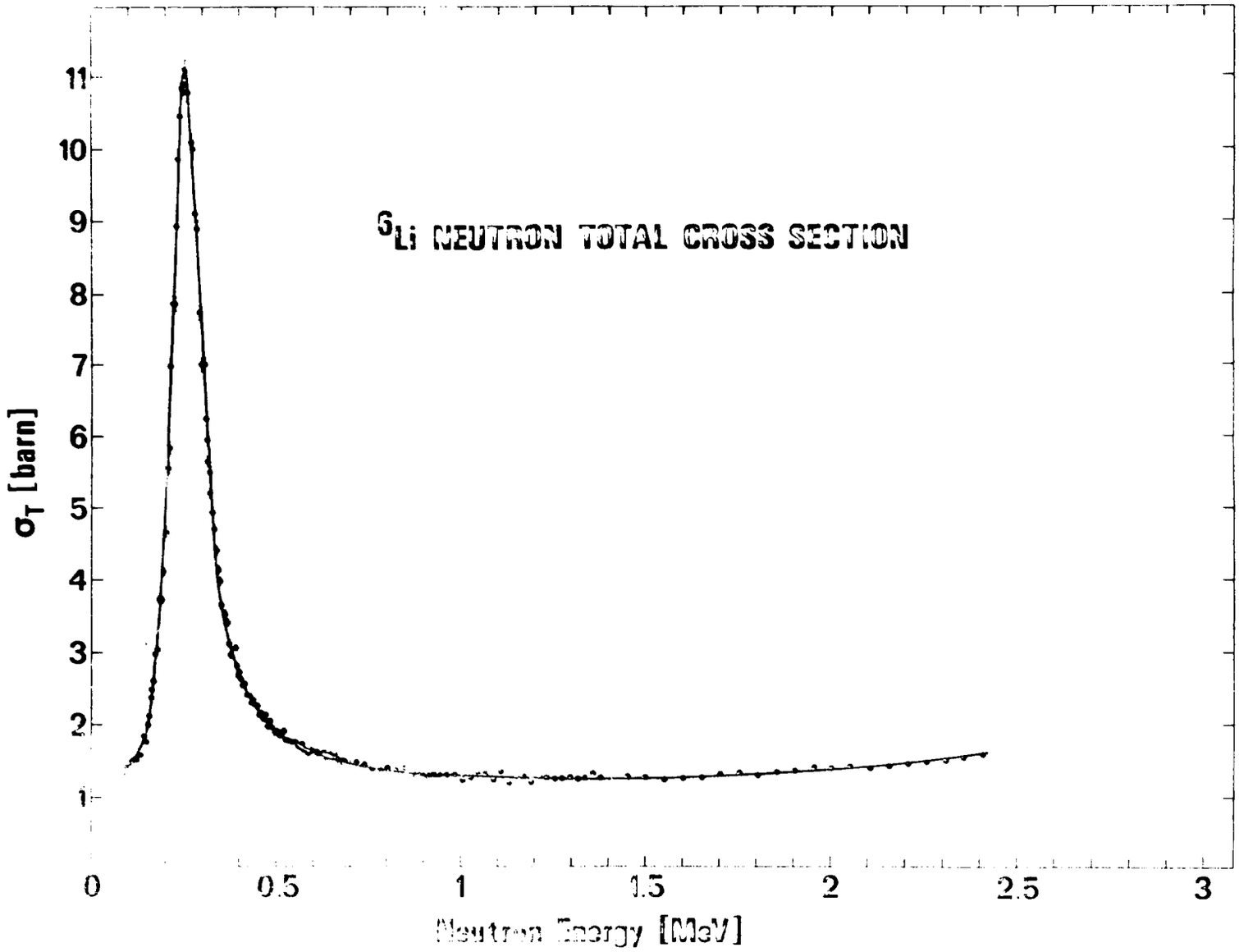
^{6}Li NEUTRON TOTAL CROSS SECTION
σ_T [barn]
11
10
9
8
7
6
5
4
3
2
1
0
0.5
1
1.5
2
2.5
3
Neutron Energy [MeV]

Fig. 3.1

Measurements of the ^{6}Li to $^{10}B(n,\alpha)$ Cross-Section Ratio

C. Bastian, G. Le Dez, E. Wattecamps

The smooth shape of the $^{6}Li(n,\alpha)T$ cross-section, its size, the absence of sizeable competing reactions and the use of ^{6}Li in glass-scintillators makes this reaction best suited as a secondary standard. Unfortunately, the measured cross-section data do not converge satisfactorily, even on the peak value of the resonance around 250 keV. A measurement of the (n, α) cross-section ratio of ^{6}Li to ^{10}B from 100 eV to possibly 1 MeV, using the Xe-gas scintillation technique is being prepared. Tests of the electronic equipment and operation of a Xe-gas purification system are in progress now. Foreseen as samples are thin films of ^{10}B and ^{6}Li deposited on the inner surfaces of thin quartz cylindrical shells of 8.0 cm radius and 10.0 cm length. The neutron beam is perpendicular to the axis of the cylinder. Two U. V. photomultipliers on the flat faces of the cylinders detect in coincidence the scintillations produced by the reaction products escaping inwards from the cylindrical sample. This geometry allows the use of thin large area samples and reduces the influence of the anisotropy of the $^{6}Li(n,\alpha)T$ reaction. A turnable sample changer, now in the late design phase, will bring the sample in position between the viewing ports and rotate it there slowly around its own axis in order to compensate for non uniformities in the density of the deposit. On command, the sample will be changed in order to irradiate ^{6}Li and ^{10}B under the same conditions, i.e. without changing the Xenon filling of the sample changer. The Xenon gas will be circulated continuously over a Titanium oven to discard quenching impurities.

3.2. Determination of $^{197}Au(n,\gamma)$ Cross-Sections in the 0.1 to 3.0 MeV Region.

A. Paulsen, H. Liskien, R. Widera, F. Arnotte

682041 Measurements of the $^{197}Au(n,\gamma)$ cross-sections to an accuracy of
692317 about ± 5% by means of the activation technique are in progress at
701025 the 3.7 MV Van de Graaff accelerator. These measurements in the
721073 0.1 to 3.0 MeV neutron energy region aim at resolving discrepancies between existing data in the 0.3 to 1.5 MeV energy region and to provide more information above 2 MeV where presently little exists. The discrepancies amount up to 20% and the results from direct detection techniques seem to be systematically lower than those from activation measurements. Irradiations at 200, 300, 400, 500, 625, 737, 875 and 895 keV relative to the H(n,n) cross-section by means of a proton recoil proportional counter are finished. A minimum of four runs were made at each energy. It was not possible to get reliable and reproducible results below 200 keV. When approaching the threshold of the neutron source reaction (in this case $^{7}Li(p,n)$) from above by decreasing the incident proton energy the relative neutron energy difference between 0° and 180° emission direction is strongly increasing. Consequently [illegible] neutrons become increasingly effective in distorting the capture measurements. The preliminary results are in reasonable agreement with the existing data but are again systematically higher than recent direct detection results from LE RIGOLEUR (Cadarache, 1973). The deviation amounts up to 15% at 400 keV. Excellent agreement was found at [illegible] keV with the result of ROBERTSON et al. (NPL, 1969) at 966 keV. A more detailed discussion can only be given when all measurements and data evaluations are finished. Measurements between 1.0 and 2.25 MeV have been carried out but had to be confirmed by remeasurements with new accelerator targets. These measurements and new [illegible] in the energy range from 2.25 to 3.0 MeV are in progress.

3.3. Measurements Pertaining to Absolute Fission Cross-Section Data

682072 691328 691821

Measurements and Normalization of the Neutron Induced Fission Cross-Section of ^{241}Pu in the Energy Region from 0.01 eV to 50 eV.

R. Barthélémy, G. Le Dez, C. Wagemans

These measurements complete a series of experiments and evaluations by DERUYTTER and WAGEMANS (Journ. of Nucl. En. 25 (1971) 263; 26 (1972) 293 and Nucl. Sci. & Engn. 54 (1974) 423) on the low energy neutron induced fission cross-sections of the four common fissile isotopes and of their normalizations. All the measurements were performed at the same 8 m flightpath using the same basic apparatus. The fission cross-section was obtained via a direct comparison of the fission rate and the $^{10}B(n,\alpha)$-rate detected with surface barrier detectors placed on both sides of a back-to-back ^{241}Pu-^{10}B foil. The background - which was very low - was determined with the black resonance technique. The measurements are finished and analysed. The relative fission cross-section curve obtained was normalized at 0.0253 eV to σ_f (2200 m/s) = 1019 ± 8 i.e. the value recommended in "The 3rd IAEA review of the 2200 m/s and 20°C Maxwellian neutron data for ^{233,235}U and ^{239,241}Pu" (F. DE CORTE et al., to be published). Several fission and resonance integrals are calculated from the so normalized σ_f-curve and compared with other results. A suitable fission integral is proposed for further normalization purposes:

$$\int_{12.0\ \mathrm{eV}}^{20.0\ \mathrm{eV}} \sigma_f(E)dE = (1366 \pm 13)\ \mathrm{b.eV}$$

661043 et al on page 68 and 69 of WRENDA list

Measurement and Normalization of the Neutron Induced Fission Cross-Section of ^{235}U in the Energy Region 5 eV - 30 keV.

R. Barthélémy, G. Le Dez, C. Wagemans

These measurements are the logical extention towards higher energies of the previously published absolute fission cross-section measurements at 2200 m/s (DERUYTTER et al. Journ. Nucl. En., 27 (1973) 645), and of the measurements in the energy region 0.01 eV - 20 eV. The latter were normalized to the first (DERUYTTER and WAGEMANS, Journ. Nucl. En., 25 (1971) 263). The aim of the pre-

sent experiment was to obtain accurate fission integrals in the high energy region carefully normalized to the previously mentioned results. The measurements were performed at a 30 m flightpath of the Linac under similar conditions as the above mentioned experiment i.e. the fission rate and the neutron spectrum were measured simultaneously with surface barrier detectors on each side of a back-to-back ^{235}U and ^{10}B layer. The measurements are now finished and are being analysed. Absolute fission cross-section data from thermal up to 30 keV will be available soon. Integration of these data in well defined parts of this energy range yields accurate normalization integrals. These integrals might be used for renormalization and reduction of discrepancies between published data.

The Determination of the Fission Cross-Section of ^{233}U from 0.002 to 0.15 eV and its Reference Value at 2200 m/s.

621035

621036 J. Brulmans, R. Buyl, E. Wattecamps

692342

To fulfil requests of WRENDA 74 and on request of the IAEA accurate fission cross-section measurements of ^{233}U and ^{235}U in the thermal energy range and the reference value at 2200 m/s will be performed. The chopper facility has been brought into operation and σ_f measurements of ^{233}U are in progress. Apart from slight modifications in the data acquisition system the measuring procedure is identical to the already well described technique used in former measurements. (A. DERUYTTER et al., J. Nucl. En. 27 (1973) 645). The ^{233}U samples are available now with an absolute composition relying on the latest half-lives value measurements of VANINBROUKX (See Sec. 5.1. this report). A sample changer based on the Geneva wheel principle is used. Two boron standard layers and two fission samples are brought alterntively into the neutron beam. The reproducibility in the sample detector distance was measured to be within [illegible] mm. The flightpath was measured to a relative uncertainty of [illegible] and the long range stability of the electronic equipment is satisfactory.

3.4. Participation in the International Fast Neutron Fluence Intercomparison organised by BIPM.

H. Liskien, A. Paulsen, R. Widera

Most published cross-sections depend on a single method of flux measurements, and it is likely that some of the discrepancies between different groups result from an underestimation of the error in flux. Therefore the EANDC symposium on "Neutron Standards and Flux Normalization" in 1970 endorsed a proposal of the CCEMRI [+)] Section III committee of BIPM (Bureau International des Poids et Mesures) to carry out an intercomparison of flux measurements with transfer instruments in well characterised neutron fields at several laboratories. This comparison involves the calibration of "transfer instruments" by the participating laboratories at specific energies. Together with four other laboratories (NRC Ottawa, BIPM Paris, CEN Cadarache and NPL Teddington) directly represented in the BIPM-CCEMRI-committee, CBNM participated in the first round, which is primarily intended to gain experience in transfering instruments. At the CBNM the following results were obtained:

Neutron energy (MeV)	Transfer instrument	Sensitivity (counts/n/sr)	CBNM method
0.250 ± 0.014	Bonner sphere	$(5.31 \pm 0.21) 10^{-6}$	prop. counter 580 Torr H_2, 20 Torr CH_4
2.200 ± 0.074	Bonner sphere	$(7.61 \pm 0.27) 10^{-6}$	recoil telescope
2.500 ± 0.079	Bonner sphere	$(7.15 \pm 0.24) 10^{-6}$	recoil telescope
2.500 ± 0.106	Bonner sphere	$(6.90 \pm 0.25) 10^{-6}$	prop. counter 1200 Torr CH_4
14.80 ± 0.29	^{238}U fission chamber	$(6.50 \pm 0.25) 10^{-6}$	recoil telescope

Results from all five laboratories having participated were discussed recently in Paris and final evaluation is underway.

+) Comite Consultatif pour les Etalons de Mesures des Rayonnements Ionisants

A copy of a 'directional counter' (NIM 88 (1970) 1) has been received from CEN Cadarache and made operational at the Van de Graaff laboratory. Its efficiency has been established at Cadarache but will also be determined at Geel yielding additional information about the reliability of the developed flux measuring devices at Geel and Cadarache.

4. NON-NEUTRON NUCLEAR AND ATOMIC DATA

Abstract

Measurements of non-neutron nuclear and associated atomic data, in which international committees, like INDC, seem to be more and more interested, have been performed at CBNM mostly by the Radionuclides Group. Reliable values can only be obtained, if many independent methods of measurement are employed and contineously improved. A part of the effort is devoted in this field.

A new value of the half-life of ^{233}U of $(1.5925 \pm 0.0040) \cdot 10^5$ y is now available that is in good agreement with a recently published result measured at ANL at Argonne.

Decay parameters of various radionuclides have been determined, as e.g. those of ^{115m}In, which are important in reactor dosimetry.

A survey on "Orbital Electron Capture by the Nucleus" and an updated edition of the report on "Isotope Abundances and Atomic Weights of the Elements" have been prepared.

4.1. Nuclear Data

Compilation of the Half-Lives of Actinides

R. Vaninbroukx

An accurate knowledge of the half-lives of the actinides is of particular interest for several nuclear applications. Often the spread of the published values is many times larger than that expected from the accuracies claimed. Therefore a compilation of the reported half-lives of the most used long-lived actinides has been made. (R. VANINBROUKX, EUR 5104e (1974), The half-lives of some long-lived actinides: A compilation). "Best" values and limits of uncertainties were proposed; they are given in Table 4.1.

Table 4.1: Proposed half-life values

Nuclide	Half-life
^{232}U	$(72 \pm 2)y$
^{233}U	$(1.592 \pm 0.003)10^5 y$
^{234}U	$(2.446 \pm 0.007)10^5 y$
^{235}U	$(7.038 \pm 0.020)10^8 y$
^{236}U	$(2.34 \pm 0.20)10^7 y$
^{238}U	$(4.468 \pm 0.010)10^9 y$
^{238}Pu	$(87.8 \pm 0.8)y$
^{239}Pu	$(2.430 \pm 0.025)10^4 y$
^{240}Pu	$(6.55 \pm 0.07)10^3 y$
^{241}Pu	$(14.5 \pm 0.5)y$
^{242}Pu	$(3.87 \pm 0.05)10^5 y$
^{244}Pu	$(8.2 \pm 0.1)10^7 y$
^{241}Am	$(432 \pm 4)y$
^{252}Cf	$(2.64 \pm 0.02)y$

The aim of the compilation was also to show where further accurate measurements are necessary in order to resolve existing discrepancies.

Determination of the Half-Life of ^{233}U

J. Broothaerts, P. De Bièvre, B. Denecke, M. Gallet, G. Grosse, Y. Le Duigou, W. Leidert, R. Vaninbroukx, V. Verding and W. Zehner

The determination of the half-life of ^{233}U has been completed (R. VANINBROUKX, P. DE BIEVRE, Y. LE DUIGOU, A. SPERNOL, W. VAN DER EIJK, and V. VERDINGH, The half-life of ^{233}U, to be published). The method is based on the measurement of the specific activity of ^{233}U samples by α-ray counting techniques, and on the determination of their uranium content. The samples were prepared from two different enriched material (99.76% ^{233}U and 99.999% ^{233}U, respectively) either by quantitative dissolution and drop deposition (DD) or by electrospraying (ES). The activity

was determined by three widely different methods:

(1) counting of α rays in a defined low geometry solid angle (LG);

(2) counting of α rays by liquid scintillation (LS), and

(3) counting of α rays in a 4π gas-filled proportional counter (4π).

The uranium content of the samples was determined by two independent methods: mass spectrometric isotopic dilution (ID) and controlled potential coulometry (CPC). The results of the different series of measurements performed since 1969 are given in Table 4.2. These result show the improvement of our methods during the last years.

Table 4.2. Half-life of ^{233}U

Series	Year of measurem.	Sample prep. technique	U-determ. method	activ. determin.	^{233}U half-life in 10^5 y
1	1969	DD	ID, CPC	LG, LS, 4π	1.5957±0.[illegible]
2	1969	DD	ID, CPC	LG, LS, 4π	1.5952±0.[illegible]
3	1972	DD	ID, CPC	LG, LS, 4π	1.5875±0.[illegible]
4	1973	DD	ID, CPC	LS	1.5901±0.[illegible]
5	1973	DD	ID, CPC	LG, LS, 4π	1.5974±0.[illegible]
6	1974	ES	ID	LG	1.5921±0.[illegible]
7	1974	ES	ID	LG	1.5914±0.[illegible]
8	1974	ES	ID, CPC	LG, LS	1.5[illegible]
9	1974	ES	ID, CPC	LG, LS	1.5[illegible]

The final value for the half-life of ^{233}U was determined to be

$T_{1/2}(^{233}U) = (1.5925 \pm 0.0040)10^5$ y.

The quoted uncertainty is the overall uncertainty on a 90% confidence level, taking into account statistical and system uncertainties.

Determination of the Half-Life of ^{239}Pu

G. Grosse, W. Oldenhof and R. Vaninbroukx

Measurements to determine the half-life of ^{239}Pu have been started using similar methods as those described above to ^{233}U.

In preliminary experiments the stability of the plutonium solutions in the organic scintillators was tested. It transpired that mixtures of aqueous sol. (50 μgPu/ml 5 N HNO_3) and the organic scintillators (Dioxane+PPO+naphthalene+TOPO), which have been successfully used in the liquid scintillation measurements with uranium solutions, were completely unstable. It was found eventually that a good long term stability could be obtained when 100 μg zirconium (in the form of its nitrate), per ml plutonium solution was added. In Table 4.3 the stability of two samples over a period of two months is shown. For each sample 25 measurements were taken.

Table 4.3. Long term stability of Pu-measurements by liquid scintillation

Sample	Reproducibility Stand. dev. ± %	Stability: slope of the observed activity in % per month
1	0.03	(+0.05 ± 0.02)
2	0.01	(+0.02 ± [illegible])

Determination of the ^{95}Zr Half-Life

H.H. Hansen

The decay of three $^{95}Zr+^{95}Nb$ sources has been followed with a Ge(Li) detector for periods of about three ^{95}Zr half-lives. Sources were made by depositing a droplet of the radioactive solution onto gold coated VYNS foils and by encapsulating the radioactive material in a small Al container. One of the sources has been measured under two different geometrical conditions. The activities of the sources were about 50 μCi at the beginning of the experiments. The spectra were treated by pulse rate summation for both the 724 and the 756 keV γ-ray peaks within fixed energy limits. The individual results show no significant dependence on the type of the radioactive source, on the geometrical conditions or on the different γ-ray peaks being treated. The preliminary result is $T_{1/2}(^{95}Zr) = 64.0d$. The measurements

will be continued.

Measurement of Decay Scheme Data of ^{115m}In

E. De Roost, H.H. Hansen, W. van der Eijk and R. Vaninbroukx

The decay of ^{115m}In has been investigated using accurate counting methods. (H.H. HANSEN, E. DE ROOST, W. VAN DER EIJK, and R. VANINBROUKX, Z. Physik 269, 155 (1974), The decay of ^{115m}In). The emission rate of conversion electrons plus β^- particles was determined with a $4\pi\beta$ proportional flow counter. The total and K-shell internal conversion coefficients of the 336 keV γ-ray in ^{115}In were measured by the (conversion electron)(x-ray) coincidence method using combinations of a Si surface barrier with a NaI(Tl) detector and of a magnetic β-spectrometer with a high energy resolution Si(Li) detector, respectively. The conversion ratio R = K/(L+M+...) was deduced from electron spectra recorded with the magnetic β-spectrometer. The 336 keV γ-ray emission rate of all sources used was determined with a calibrated NaI(Tl) γ-ray spectrometer. A Ge(Li) detector has been used to determine the relative intensity of the 497 keV γ-ray in ^{115}Sn. From the results the following has been deduced: the 336 keV γ-ray emission per decay (45.9±0.1)%, the total internal conversion coefficient (1.073±0.014), the K-shell internal conversion coefficient (0.843±0.012), the conversion ratio (3.63±0.07), the β^--transition per decay going to the ground state (5.0±0.7)% and to the first excited level in ^{115}Sn (0.047±0.002)%, and the 497 keV γ-ray emission (0.103±0.004)%. From the obtained internal conversion data it follows that the 336 keV γ-ray transition is of M4 character with an E5 admixture of less than (3.5±1.5)%. The half-life of the isomeric state ^{115m}In has been determined by four different methods. The results are 4.486±0.004h.

Measurement of Internal Conversion Data of the 165 keV γ-ray in ^{139}La

H.H. Hansen and D. Mouchel

The internal conversion of the 165 keV γ-ray transition in the decay of ^{139}Ce has been reinvestigated. The emission rate of

K-shell internal conversion electrons was determined with a (K conversion electron)-(K x-ray)-(K x-ray) triple coincidence measurement using a magnetic β-spectrometer and two Si(Li) detectors of high energy resolution. Furthermore, conversion electron ratios were obtained from electron spectra recorded as a function of momentum. The γ-ray decay rate of the used sources has been taken from measurements with a calibrated NaI(Tl) γ-ray spectrometer. The following preliminary results have been deduced: α_K=0.215, α=0.252, K/(L+M+...)=5.85, K/L=7.46, and L/M+...=3.65. Errors of about ± 2% have to be assumed for the internal conversion coefficients entirely due to the low triple coincidence rate. The errors on the conversion ratios are between ±2 and ±5%, mostly due to graphical spectrum treatment and extrapolation.

Review on Orbital Electron Capture by the Nucleus

W. Bambynek

A review on "Orbital Electron Capture by the Nucleus" has been prepared in collaboration with American, British and German scientists. The survey covers the following subjects: electron capture theory; experimental methods to measure L-capture to K-capture ratios, M-capture to L-capture ratios, and electron capture to positron emission ratios; critical evaluation of the experimental results and comparison with those predicted from theory; theory and experimental verification of radiative electron capture; atomic transitions accompanying nuclear electron capture. The second draft is nearly finished. It is planned to have the review published in 1975.

Evaluation of Decay Scheme Data

W. Bambynek, H.H. Hansen, T.D. Mac Mahon [+], and P. Venugopala Rao [++]

Evaluations of nuclear and atomic decay scheme data of the

[+] London Reactor Center, UK

[++] Emory University, Atlanta, Ga, USA

nuclides ^{22}Na and ^{204}Tl have been studied. They are performed according to the rules, which were discussed by the European Working Group for Evaluation of Nuclear and Atomic Data and which are published by Grinberg et al. (B. GRINBERG, J.P. BRETHON, F. LAGOUTINE, Y. LE GALLIC, J. LEGRAND, A.H. WAPSTRA, H.M. WEISS, W. BAMBYNEK, E. DE ROOST, H.H. HANSEN, A. SPERNOL, Critical Evaluation of Decay Properties and Compilations of other Useful Data of Frequently Used Radionuclides, Atomic Energy Review 11, 515 (1973)).

4.2. Atomic Data

Measurement of Photoelectric Cross Sections

H.H. Hansen and K. Parthasaradhi [+]

Total photon interaction cross-sections have been measured in the elements Al, V, Cu, Mo, Ta, Au, and Pb at eight photon energies between 165.8 and 1332.5 keV. Measurements were made with the transmission technique on a "good geometry" set-up using a high energy resolution Ge(Li) detector. Photons of the required energies were obtained from ^{22}[illegible] ^{54}Mn, ^{60}Co, ^{95}Zr/^{95}Nb, ^{137}Cs, and ^{139}Ce) sources [illegible] about 20 µCi strength. The [illegible] thicknesses were between 1.5 and 20 g/cm^2 in order to obtain photon interaction [illegible] of between 30 and 70%. The geometry was chosen in such a way that it defined a solid angle of about $2 \cdot 10^{-4}$ corresponding to a photon beam opening of [illegible] than 2°. Photoelectric cross-sections will be obtained by subtracting calculated contributions due to coherent and incoherent scattering from the observed total interaction cross-sections.

[+] Andhra University, Visakhapatnam, India

Measurement of K-Shell Ionization During β^- Decay

H.H. Hansen

Internal ionization during β^- decay has been studied for the isotopes ^{143}Pr and ^{204}Tl. (H.H. HANSEN, Physica Fennica 9 (S1), 264 (1974). K-shell Internal Ionization Probabilities in Nuclear Beta Decay of ^{143}Pr and ^{204}Tl). The total K-shell internal-ionization probability per β^--decay, P_K, has been determined from the number of emitted K x rays and the total β^--decay rate. Radioactive sources were made by drop deposition onto gold coated VYNS foils of total thickness between 50 and 150 $\mu g\ cm^2$. As both radioactive materials show a complex K x-ray spectrum (^{143}Pr is slightly mixed with other rare earth isotopes and ^{204}Tl has a small EC branch) advantage was taken of the high energy resolution of a Si(Li) detector (260 eV for the Mn K_α x rays of 5.9 keV) in order to discriminate against all x rays not originating from the daughter nucleus after β^- decay. The β^- particles from the sources were absorbed in Be disks of suitable thicknesses. The detection-efficiency calibrations were performed using x rays emitted from ^{241}Am sources of known disintegration rate. The decay rates of the used β^--ray sources were determined by β^- counting measurements with a calibrated end window counter and by liquid scintillation counting. The results are $P_K = (4.94 \pm 0.22) \cdot 10^{-4}$ and $(1.12 \pm 0.09) \cdot 10^{-4}$ for ^{143}Pr and ^{204}Tl, respectively. The error given on P_K is composed of the standard error and a total systematic error characteristic for the series of measurements. The total systematic error is the arithmetic sum of the individual components due to the efficiency calibration, the determination of the disintegration rate, and the nuclear and atomic constants used. The agreement of these values and with theory and with other recent experimental results is very satisfactory.

Isotope Abundances and Atomic Weights of the Elements

P. De Bièvre, M. Gallet

In the frame of the "International Mass Spectrometric Evaluation

Group", (IMSEG) which was set up by the IUPAC's Commission on Atomic Weights, a thoroughly reworked and updated edition of the report on Isotope Abundances and Atomic Weights of the Elements has been prepared. From this compilation best estimates of natural isotope abundances, uncertainties on atomic weight values due to upper limits of neighbouring isotopes, and observed ranges of natural abundance variations have been evaluated and submitted to IMSEG.

Collaboration was provided to Prof. Münzel (KFK) in order to furnish the natural isotope abundances of the elements for the planned 1974 edition of the German "Nuklidkarte".

4.3. Metrology of Radionuclides

International Intercomparison and Standardization of Radionuclides

E. Celen, G. Grosse, R. Vaninbroukx and W. Zehner

In the frame of an intercomparison, that was organized by the Bureau International des Poids et Mesures (BIPM), Paris, the radioactive concentration of a ^{139}Ce solution was determined (R. VANINBROUKX and E. CELEN, CBNM internal note: CBNM/RN/5/74, Determination of the specific activity of a ^{139}Ce solution for a BIPM intercomparison using the 4π(AX)-γ coincidence method). The objective was to investigate the efficiency extrapolation technique in (4π Auger electron plus x-ray)-(γ-ray) coincidence counting for a nuclide with a daughter having a converted γ ray. Other participants were the Atomic Energy Commission Limited (AECL), Chalk River (Canada); the Bureau International des Poids et Mesures (BIPM), Paris (France); the National Physical Laboratory (NPL), Teddington (GB), and the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig (Germany). The material was distributed by the NPL. Variation of the efficiency in the "β" counter, which is the basis of the extrapolation method, was obtained by covering the sources with Al foils of increasing thickness. The statistical uncertainty (99.7% confidence level) of the result is 0.4% and the systematic uncertainty was estimated to be 1.4%. The result agrees within

0.6% with that of the NPL. The results of the other participants are not yet available.

Reference sources of ^{241}Am of special size, not commercially available, were prepared and standardized on request from the Studiecentrum voor Kernenergie (SCK), Mol (Belgium).
The overall accuracy of the results on the basis of a 99.7% confidence level was 0.5%.

Improvements of Methods to Measure γ and x Rays

G. Grosse, D. Reher and R. Vaninbroukx

The accuracies of the experimental γ efficiency curves of a 3"x3" NaI(Tl) detector in three defined solid angles and two Si(Li) detectors,each in one defined solid angle,have been improved by recalibration with several standardized sources of ^{109}Cd, ^{125}I, ^{133}Ba, and ^{241}Am.

A 4" dia x 1/2 thick detector has also been commissioned to be used to measure x rays of low energy ($E \geq 10$ keV) under three definied solid angles. Because of the large diameter of the crystal the instrument is nearly insensitive to the eccentricity of sources prepared by drop evaporation, and hence better precision can be obtained.

For the determination of low intensity γ-transitions and radiochemical impurities an anti-Compton/pair spectrometer is under development (see Section 9.4.).

For the determination of x rays a solid state sandwich detector is in construction (see Section .4.).

Improvements of Method to Measure β^- Rays

H.H. Hansen, K. Hofmans, D. Mouchel, H. Nerb, E. Sattler and H. Schipke

New electronic instrumentation has been developed (E. SATTLER, H.H. HANSEN, K. HOFMANS, D. MOUCHEL, H. NERB and H. SCHIPKE, Nucl. Instr. Meth., in press. Automatic Control and Data Acquisition of Magnetic Beta Ray Spectrometer Measurements) in the course of replacing a valve current supply and control system.

The installation of thyristorised switching regulators as magnet current supply units with their inherent low heat production overcomes stability and reliability problems occuring due to excessive ambient temperature variation. The influence of the history of the magnet has been reduced considerably by a reproducible completely automatic demagnetisation procedure. Use has been made of CAMAC standard equipment as much as possible. The quality of the overall performance of the spectrometer has been demonstrated by a series of measurements and tests. An overall stability of $1.7 \cdot 10^{-5}$ /°C for measurements of 24 hours and longer and at 10A current range has been achieved. The reproducible adjustment of the magnetic field is a measure for the reliability of the controlling and demagnetising procedure. It has been shown that a preselected current value could be reached within a variation of $\pm$ 0.002%.

Improvements of Methods to Measure α Rays

W. Bambynek, B. Denecke

Some aspects of α-counting of thin sources have been reinvestigated in order to improve the accuracy attainable on activity measurements. A large part of the uncertainty is in the estimation of the counting solid angle for large inhomogeneous sources and a device is being constructed to automatically scan over the source. In addition the scattering of the particles by the wall of the chamber and the residual gas has been investigated experimentally and in consequence it is now possible to calculate the uncertainties due to this effects more accurately.

Numerical Methods to Evaluate Spectrum Data

G. Bortels

A new procedure for the numerical evaluation of the total area of ^{238}Pu and (^{239}Pu+^{240}Pu) peaks in α-ray spectra has been developed. A typical spectrum is shown in Figure 4.1.

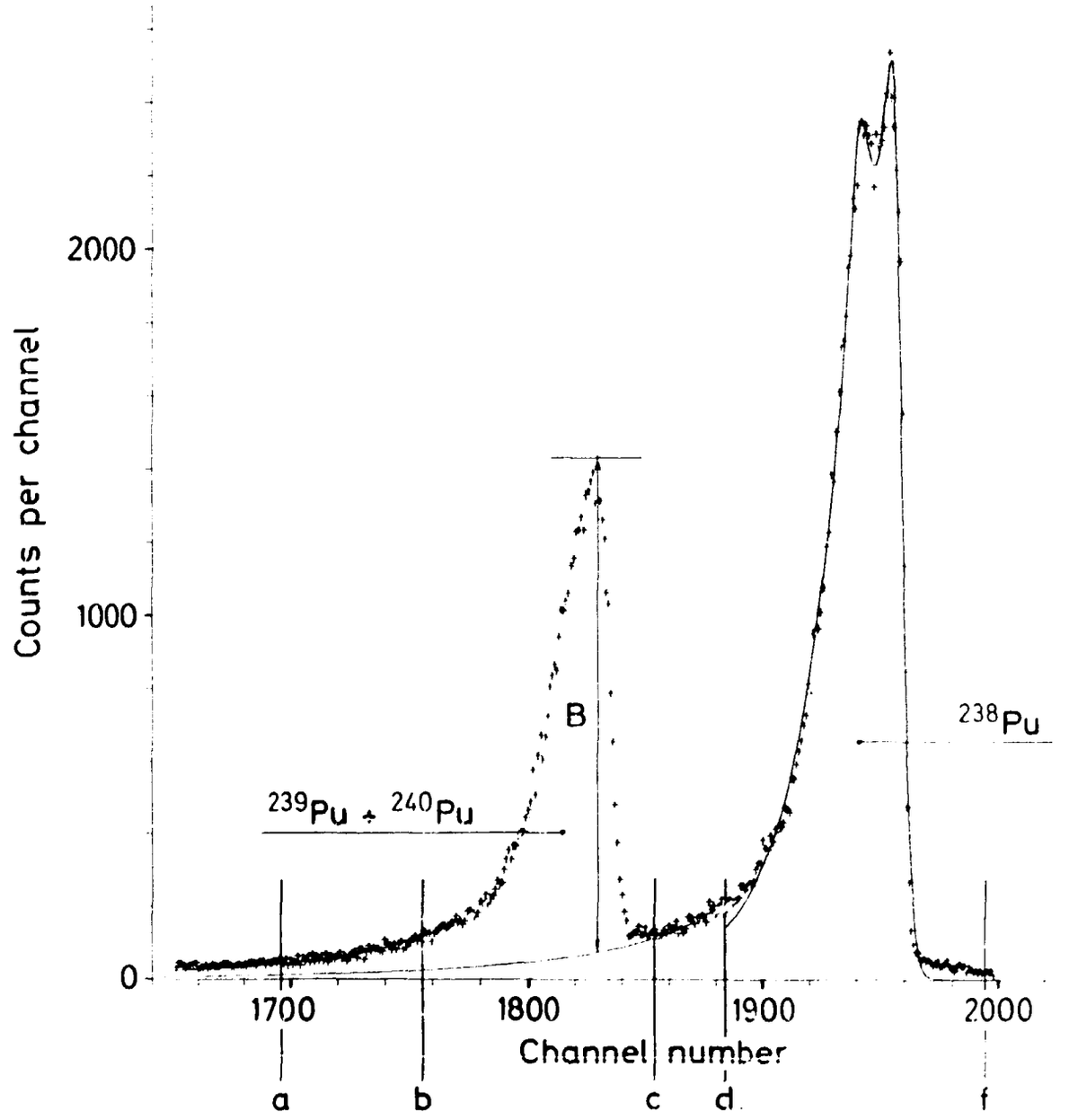

Fig. 4.1 Alpha ray spectrum of a Pu sample

The experimental data which belong to the ^{238}Pu group in the region (d, f) are fitted with a sum of two (i=1, 2) skewed Gaussians according to

$$f(E) = \sum_i A1_i \exp\left(\frac{-(E-A3_i)^2}{A2(1+A5(E-A3_i)^{A4})} \right), \qquad (1)$$

where $A1_i$ is the peak height, A2 is the resolution parameter, $A3_i$ is the peak energy, A4 is the skewing parameter, and A5 is the tailing parameter (M. P. TRIVEDI, Progress Report 1969-1970, NYO-844-81). The part of the single-peak-spectrum above $A3_i$ is presumed to have Gaussian shape, hence A5=0 for $E \geq A3_i$.

The contribution of the ^{238}Pu group to the experimental data in the region (a, b) is found by iteration as follows. With an initial estimate of the fractional contribution of ^{238}Pu in (a, b), the tail (a, d) of the ^{238}Pu group is fitted with the model of Eq. (1) using the constants $A1_i$, A2, $A3_i$ from the previous fit in (d, f). This gives the parameters A4, A5 in the region (a, d). Using these parameters and assuming that the heights of ^{239}Pu and ^{240}Pu subgroups are both B/2, the fractional contribution of ^{238}Pu in (a, b) is calculated according to Eq. (1) with i=3, 4, 5, 6, 7. All the energy differences and ratios of peak heights are known from the decay schemes.

Areas under the Pu groups are obtained by integrating the tail region and by summing up the corrected data outside that region. The nonlinear least squares program which was used is a shortened version of an existing program (E. VAN DER VOORT, B. DOUPEMA, EUR 4777e (1972) ; E. VAN DER VOORT, J. P. HALLEUX, EUR 4959e, (1973)).

5. SAMPLE AND TARGET PREPARATION

Abstract

During this year we have continued to make special samples and targets for CBNM groups and for outside users. The total number of samples was 2056 covering 103 different orders.

About 60 % of these orders are for bulk samples not requiring support on a backing and are used mainly as :

- reference and standard materials for community programmes organized by the EURISOTOP Office of DG III (Industrial Affairs)

- materials with certified composition in solid state physics and analytical chemistry (e.g. spike materials for the safeguards analyses).

The remainder are very thin samples usually requiring a backing. They are used as targets for nuclear measurements.

5.1. Bulk samples

E. Freistedt, J. Mast, M. Parengh, F. Peetermans, J. Triffaux, J. VanAudenhove

These samples are prepared mainly by "clean" machining, powder pressing, rolling or quantitative alloying using the high frequency levitation melting technique.

The list of the bulk samples is given in Table 5.1.

5.2. Thin samples

M. Aerts, W. Dobma, W. Lycke, F. Michiels, G. Müschenborn, P. Rietveld, H. Ruts, H. Silvester, J. Tjoonk, J. Van Audenhove, F. Van Castel, V. Verdingh, J. Waelbers, W. Willems

The list of thin samples prepared in 1974 is given in Table 5.2.

As in previous years, a large number of thin films of trans-uranium elements have been prepared.

- The preparation of ^{243}Am and ^{241}Am targets

H. Ruts, F. Michiels, V. Verdingh

One of the difficult sets of targets which was prepared is ^{243}Am. Twelve ^{243}Am layers were requested by CEA Saclay for fission cross-section measurements in the energy region of some eV to 5 MeV and these were made by suspension spraying. A yield of about 70 % starting with 80 mCi of Am was observed.
The base material (99 % ^{243}Am)was supplied by the applicant

Work is also in progress to prepare some samples of ^{241}Am for neutron cross-section measurements. An agreement has been reached between different groups of physicists of CBNM, GfK, AERE Harwell and SCK Mol to use the same ^{241}Am samples.

The samples to be prepared by CBNM will have the following characteristics :

1. Large surface sample :
   200 x 200 mm Total activity : 6Ci
2. Sample for transmission measurements
   Diam. : 14 mm
   Canned in Al Total activity : 10Ci
3. Sample for scattering and capture measurements
   Diam. : 50 mm
   Canned in Al Total activity : 50Ci

- Investigation on the radioactive sources

W. van der Eijk, W. Zehner

Several methods for the preparation of drop sources have been compared by preparing sources from one ^{60}Co solution.
After different treatments as, e.g. addition of seeding agent, addition of wetting agents, addition of chemical reagents,

exposure to NH_3, freeze drying, the β-efficiency (ε_β) of the sources has been determined by 4π-β-γ-coincidence counting. Highest ε_β-values have been obtained with several precipitation reactions.

The α-particle spectra from sources of ^{241}Am prepared by several methods from the same solution have been compared. The methods used were : vacuum evaporation, electrodeposition, electrospraying, deposition of drops onto thin ion-exchange layers and several precipitation methods.

- Realisation of a complex multifoil target

P. Rietveld, J. Van Gestel

For the measurement of the average polarization of ^{12}B produced by polarized muons in a $\mu^- + {}^{12}C \rightarrow \nu_\mu + {}^{12}B$ reaction a joint working group from Louvain-la-Neuve and Saclay asked for a special target composed of two sets of 100 selfsupporting foils. Each foil consisted of three layers : 1500 $\mu g\ cm^{-2}$ Au, 50 $\mu g\ cm^{-2}$ C and 300 $\mu g\ cm^{-2}$ Al. The gold and carbon layers were produced by vacuum evaporation and fixed onto the commercial Al-foils by floating. The final two stacks of foils with lateral dimensions of 80 mm by 80 mm were enclosed in thin-walled Al boxes.

Table 5.1

Bulk Samples delivered in 1974

Materials	Applicants (a)	Amounts	Definition Methods (b)	Preparation Method (c)
Y Tb Fe Dy Fe Al	1) 1)	12	Q.A.	L.M.
^{6}Li	3) 6) 7)	1	S.A.-I.A. M.D.-D.C.	IMC EX.-C.
Al - Pu	4), 5)	2	Q.A.-I.A.	L.M.-R.
Pr, Pb, Re, U, Cu, V, Mo, Sn, Ta, Au, Al	6)	50	M.D.-D.C.	M.-R.-P.
Cu - Cr Cu - Fe	10)	20	Q.A.	L.M.- R.-W.D.
Ta	11) 4)	20	M.D.	C.S
U - Pu	6) 38)	100	Q.A.-I.A.	L.M.-M.-C
Ag-Al-Cu-Au-In 0.2 % each Au-Al-Cu-Ag-Pb 0.2 % each	13.	2	Q.A.	L.M.- R.-W.D.
Cu-Industrial Pb Mo, Zr, W	40)	600	-	M.
^{235}U	6) 4)	4	M.D.-I.A.	L.M.- R.-M.-C.
Th	4)	2	M.D.	R.
Ni_3Mo	4)	4	Q.A.	L.M.-R
Na, NaK	14)	2	M.D.-D.C.	M.-C.
Cu - 12 and 1,2 ppm Pt Cu - 12 and 1,2 ppm Pd	1) 2) 7) 15) to 34)	400	Q.A.	L.M.-M. R.-W.D. P

Table 5.2

Thin samples delivered in 1974

Layers	Applicants (a)	Amount	Definition Methods(b)	Preparation Methods(c)
^{252}Cf	41) 42) 43) 7) 44) 45) 39) 6) 46)	14	α -counting	S.T.
^{233}U	47) 35) 44)	20	M.D.	E.S.
^{235}U	35) 36) 37) 6) 9)	132	M.D.	E.S.
^{236}U	48) 49) 43)	10	M.D.	E.S.
^{238}U	37) 26)	116	M.D.	E.S.-S.
^{232}Th	6)	4	M.D.	S.
^{239}Pu	44) 35) 50)	10	M.D	E.S.
^{241}Am	6)	7	M.D.	E.S.
^{243}Am	44)	12	M.D.	E.S.
$^{235}UF_4$	42)	6	M.D. α -counting	V.D.
$^{238}UF_4$	4)	3	M.D.	V.D.
^{10}B, ^{11}B	12) 39) 6)	22	M.D.	V.D.
Nat. B	12)	1	M.D.	E.S.
^{182}W, ^{184}W, ^{186}W	51) 52)	11	M.D.	E.S.
^{112}Sn	51)	6	M.D.	E.S
^{91}Zr	6)	1	M.D.	S.
CsF	6) 9)	2	M.D.	S
Cs_2CO_3	6) 9)	2	M.D.	S
LiF	6) 8)	30	M.D.	V.D.
Au/C/Al	53)	250	M.D.	V.D.
Zr	4)	3	M.D	V.D.
Vyns. C		175	-	-

(a) List of Applicants

1. K.F. Jülich, G.
2. RUCA, Antwerp, B.
3. Max Planck Inst., Mainz, G.
4. S.C.K.-C.E.N., Mol, B.
5. R.C.N., Petten, N.
6. C.B.N.M.
7. C.E.A., Saclay, F.
8. P.T.B., Braunschweig, G.
9. C.N.E.N., I.
10. Univ. München, G.
11. C.N.R.S., Orsay, F.
12. Sterrenkundig Inst. Utrecht, N.
13. Institut für Spectroscopie, Dortmund, G.
14. I.A.E.A., Bucharest, H.
15. C.N.R.S., Orleans, F.
16. Labor P. Sue, Gif-sur-Yvette, F.
17. Hermes GmbH, Hanau, G.
18. B.A.M., Berlin, G.
19. Ugine Kuhlmann, Levallois, F.
20. I.N.W., Univ. Gent, B.
21. C.R.A.A., Pavia, I.
22. C.C.R., Ispra, I.
23. A.E.R.E. Analyt. Sciences, Harwell, U.K.
24. Inst. Max von Lane, Langevin, Grenoble, F.
25. Univ. Namur, B.
26. G.f. Karlsruhe, G.
27. Univ. Lyon, Villeurbanne, F.
28. C.E.N., Grenoble, F.
29. Johnson and Matthey, Royston, U.K.
30. Comptoir Lyon Allemand, Lyon, F.
31. Norddeutsche Affinerie, Hamburg, G.
32. Metallurgie Hoboken, B
33. Siemens A.G., Karlsruhe, G.
34. Degussa, Hanau, G.
35. I.A.E.A., Hungary
36. C.E.A., Cadarache, F.
37. Univ. Catania, I
38. E.E.C., Safeguards Authorities.
39. T.H. Darmstadt, G.
40. EURISOTOP, GD III (50 Industr. and Nat. Labs. of the EEC).
41. Univ. Ge[illegible], B.
42. Univ. P[illegible] G.
43. Univ. [illegible]berg, G.
44. C.E.A [illegible]ontrouge, F.
45. C.E.N. [illegible]-sur-Yvette, F.
46. Univ. Paris, F.
47. I.A.E.A., Brazil.
48. I.A.E.A., Romania.
49. C.E.N., Bordeaux, F.
50. A.A.E.C., Australia.
51. Univ. Brussels, B.
52. C.N.R.S., Orsay, F.
53. Univ. Louvain, B.

(b) Definition Methods

Q.A. : Quantitative alloying
M.D. : Mass definition
D.C. : Dimentional control
S.A. : Spectrographic analysis
I.A. : Isotopic analyses

(c) Preparation Methods

L.M. : Levitation melting
I.M.C. : Induction melting in crucible
EX. : Extrusion
C. : Canning
R. : Rolling
M. : Machining
P. : Punching
W.D. : Wire drawing
V.D. : Vacuum deposition
C.S. : Cathodic sputtering
E.S. : Electrospraying
S.T. : Self transfer
S. : Settling

5.3. Compilation on Reference Materials

Reference materials of interest to nuclear energy

Y. Le Duigou

Information has been obtained from different organizations to produce a list worldwide availability of reference materials of interest to nuclear energy. Chemical, isotopic and trace element reference materials are included but emphasis has been given to the substances of primary interest like those containing uranium and plutonium.

The catalogue will be issued as a Euratom report.

Reference materials of radioactivity

W. van der Eijk

On the request of the BCR (Community Bureau of References) of the Commission of the European Communities, a directory of certified reference materials of radioactivity has been prepared in collaboration with Dr. Gorski of the Seibersdorf Laboratory of the International Atomic Energy Agency.
This directory comprises the products of 12 suppliers of certified reference materials (CRM) of radioactivity as given in their catalogues.
Included are only products for which certificates are delivered and whose uncertainties are given according the rules defined in ICRU 12 (1968) with a confidence limit of 99.7 % or 99 %. Only those products are included where the stated uncertainties according to the above rules are less than 10 %. In total, some 2 200 items have been included.

This compilation will be published by the IAEA. A regular updating is foreseen.

5.4. Procurement [illegible] isotopes

H. Ruts, V. Verdingh

The coordination of isotope procurements from the USA was continued.
Loan requests wer[illegible] for ^{239}Pu and Pd isotopes and purchase requests were submitted to the USAEC for ^{233}U, ^{244}Pu, ^{242}Pu and ^{233}U.
Recovery and final accounting were made for ^{98}Mo and ^{234}U on loan from the USAEC research pool.

6. ACCELERATORS AND INSTRUMENTATION

6.1. Electron Linear Accelerator

Operation and Improvements of the Linear Accelerator

J.M. Salomé, R. Cools, R. Forni, F. Massardier, F. Menu, R. Pijpstra, P. Schweitzer (until 31.8.74), P. Siméone, F. Van Reeth, C. Waller

In 1974 the linear accelerator (Linac) was operated for 3750 hours. Details on klystron hours, useful beam time and maintenance are listed in Table 6.1, Figs. 6.1 and 6.2.

Table 6.1

	1973	1974
Klystron hours	3923	3870
Electron beam hours	3802	3750
Hours for maintenance and other interruptions	544	552

The accelerator was entirely used as a pulsed neutron source with an average number of 2.6 flightpaths compared with 2.[illegible] in 1973.

The modulator was operated part of the time with two EEV thyratrons (1040 h) and with two ITT thyratrons (1760 h) instead of the spark-gap switches. Several technical advantages were observed such as good overall stability allowing better performance of the electron beam, lower power consumption and increased life times of the high voltage components. Nevertheless, some difficulties occurred which were probably due to the critical design of the oil tank. Tests with the thyratrons will be taken up again next year when the system has been improved.

The new pilot oscillator 2 x 1 kW was delivered by Radiation Dynamics. Driven by a very stable constant-wave generator gated by a pin diode modulator it will improve the tuning of the accelerating wave guides.

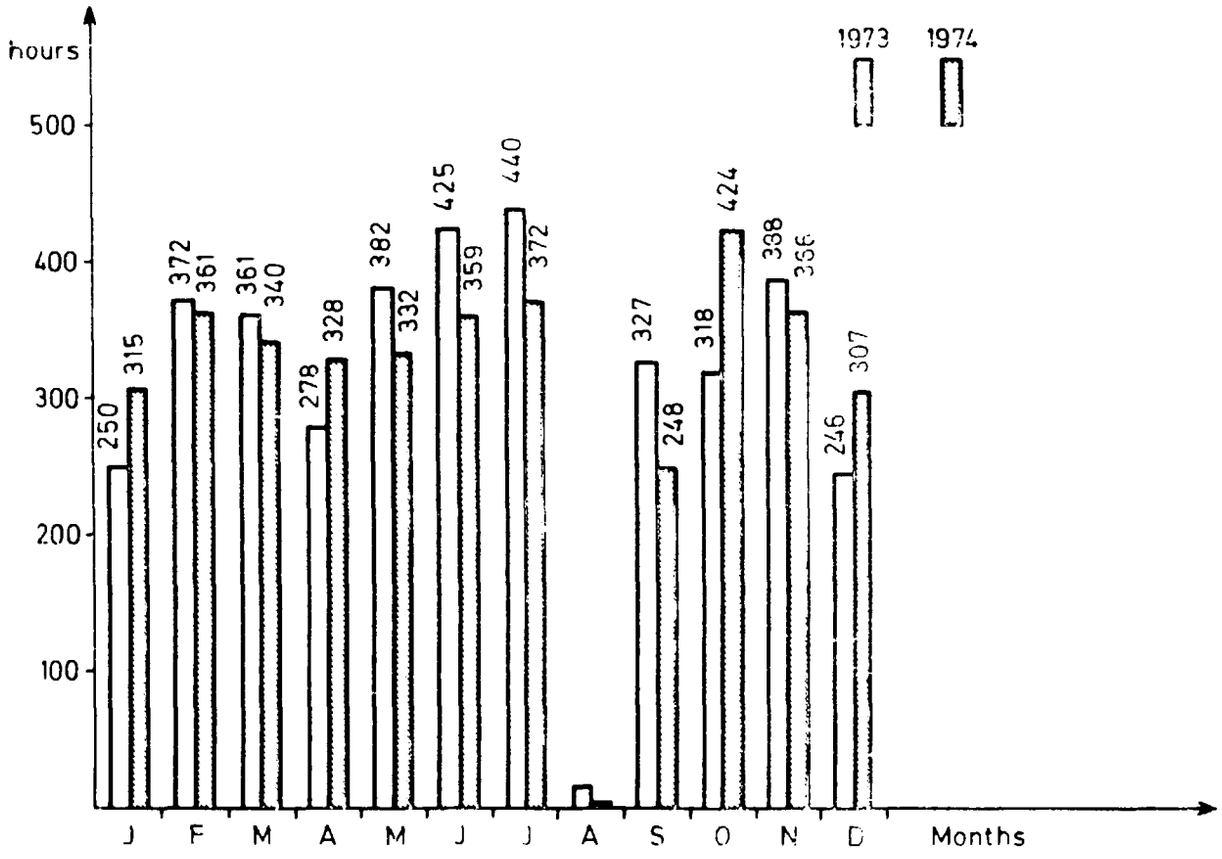

Fig 6.1 Linac operation. Useful electron beam hours per month

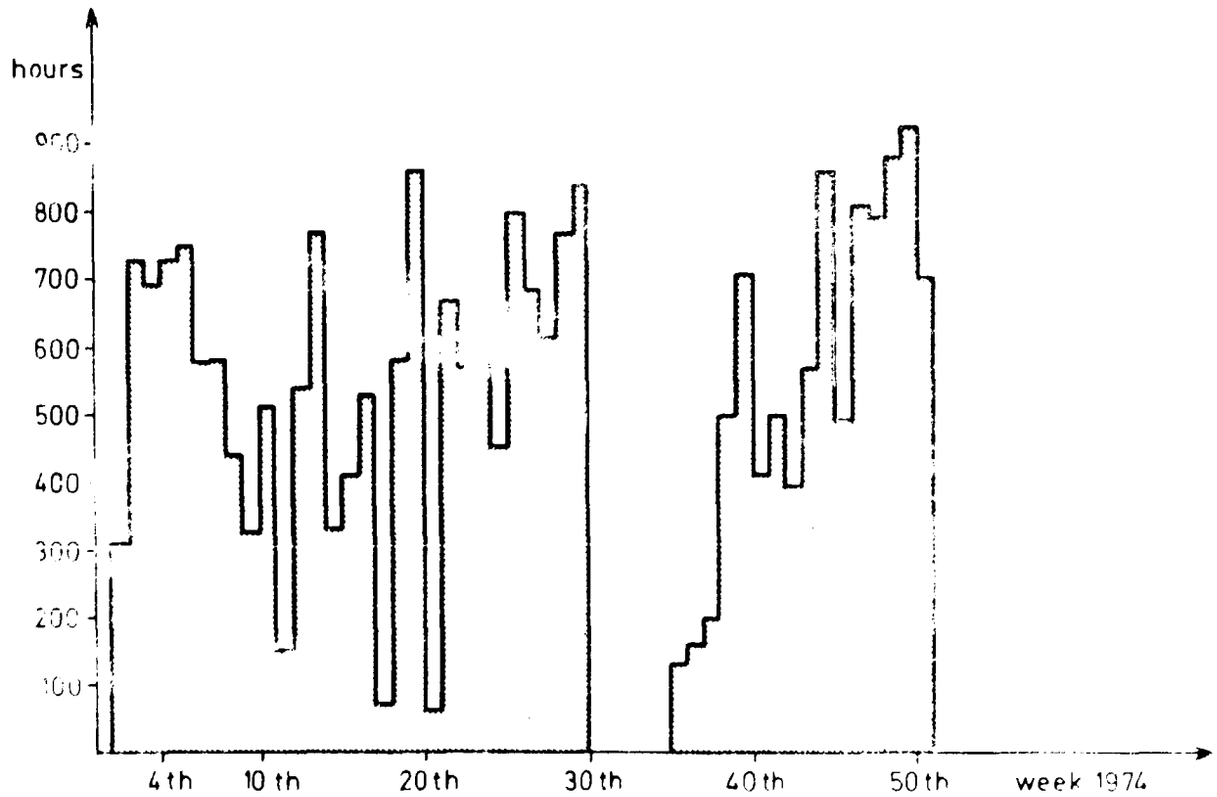

Fig 6 2 Linac operation Total neutron beam hours per week

Modernisation of the Linear Accelerator

J.M. Salomé, R. Cools, R. Forni, F. Massardier, F. Menu, R. Pijpstra, P. Schweitzer (until 31.8.74), P. Siméone, F. Van Reeth, C. Waller

The order for the modernisation of the LINAC was sent to CGR-MeV in June, 1974. It is expected that components will be delivered from September, 1975 on and installed and checked before the end of 1975. Acceptance tests are planned for February or March, 1976.

The main new parts are: a gun (35 A, 80 KV), a standing-wave buncher with modulator and two 6 m long sections. Tables 6.2 and 6.3 show the guaranteed and theoretically possible characteristics of the modernised accelerator.

Table 6.2: Guaranteed values

	Short pulses (1)			Long pulses (2)	
τ	4 ns	10 ns	100 ns	1 μs	2 μs
I	9 A	9 A	1.5 A	0.22 A	0.22 A
F	900 Hz	900 Hz	880 Hz	380 Hz	250 Hz
E	120 MeV	105 MeV	87 MeV	100 MeV	100 MeV
P	3.9 kW	8.5 kW	11.5 kW	8.3 kW	11 kW

(1) For short pulses, the energy at zero current will be 130 MeV.
(2) For long pulses, the energy at zero current will be 150 MeV.

Table 6.3: Calculated values

	Short pulses			Long pulses	
τ	3 ns	10 ns	100 ns	1 μs	2 μs
I	12 A	12 A	1.8 A	0.25 A	0.25 A
F	900 Hz	900 Hz	880 Hz	380 Hz	250 Hz
E	130 MeV	105 MeV	90 MeV	108 MeV	108 MeV
P	4.2 kW	11.3 kW	14.2 kW	10.2 kW	13.5 kW
	Calculation hypothesis: cos ϕ (buncher) = 0.72 cos ϕ (section) = 0.95			Calculation hypothesis: cos ϕ (buncher) = 0.8 cos ϕ (section) = 1	

A prototype of the new gun is being tested. Preliminary results show a peak current of 20 A (28 A cathode emission) at 50 kV (HV power supply available at present). Pulse lengths of 7 ns (FWHM) are presently achieved with this emission and it is hoped to reduce this length in the future.

Developments of Targets and Target-Moderator Configurations

J.M. Salomé, J. Wartena, R. Cools, P. Simone, F. Van Reeth

The parameters generally requested on the Linac are about 5 A, 25 ns, 65 MeV (average energy), 600 Hz. This corresponds to about 5 kW mean power. Under these conditions no problems, except damage in the surroundings such as flow ratemeter for mercury, thermocouples and security switches were noticed for the mercury cooled uranium target of 26 mm diameter.

A 30 mm diameter target with enriched uranium is now partly constructed and will be available beginning next year. A device to check possible contamination between the two front windows will be set up.

Due to very long delivery time of the main p[illegible] of a special PACIFIC type rotary joint for the rotating mercury cooled uranium target the tests with mercury under pressure were postponed to 1975.

Polyethylene [illegible] used for moderating the neutrons emitted from the linac target but it suffers from high radiation damage. Therefore the possibility of replacing this polyethylene by water has been studied.
Due to the lower proton density, ($6.67 \cdot 10^{22}$ protons/cm[illegible]r water, $8.14 \cdot 10^{22}$ protons/cm^3 for polyethylene[illegible]or) a moderated flux of 6% is expected for the water moderator. Because of the presence of oxygen instead of carbon a hardening of the spectrum can be predicted. Both effects are experimentally confirmed.

A water moderator, contained in a metallic can seems to be usable. No overheating, erosion or radiolysis has been observed.

For the can material beryllium is suggested, because it is expected to give the lowest contribution to the γ-flash and the lowest distortion of the spectrum, since its first resonance is at .62 MeV. A moderator of this type is under construction.

Background Study of a C_6F_6 Detector for Average Capture Cross Section Measurements with the Linac

G. Rohr, T. van der Veen and G. Vanpraet*

The neutron sensitivity of the C_6F_6 detector has been measured as a function of energy by scattering from thick samples of C and Pb. Structure above an energy of 10 keV has been observed, the strongest peaks in the energy range of 30 - 100 keV being assigned to resonances in fluorine at 27 keV and 50 keV. The observed peak at 36 keV, due to the aluminium canning and housing of the detector, was roughly a factor of four smaller than the yield at 27 keV in F. The time dependent background in an average cross-section measurement is generally difficult to handle. However, in this case it becomes even more difficult because the position of the background peak produced in the detector by the sample scattered neutrons [illegible] with the atomic weight of the nucleus under study. To reduce this effect it is intended to replace the C_6F_6 detector with a C_6D_6 liquid scintillator with a very thin walled aluminium container and this is under construction.

Development of a Spark Chamber for Fission Cross-section Measurements of ^{241}Am

A. Brusegan, M. Merla, E. Migneco,** H. Weigmann

Some time ago an attempt was made to measure the fission cross of ^{241}Am using a 2 g sample in a spark chamber filled with nitrogen gas, but the counter performance deteriorated with time due to the fact that a chemical compound of nitrogen was deposited on the Al electrodes. In order to avoid this disturbing chemical reaction a new gas mixture with a much lower nitrogen content is under investigation and the Al-electrodes have been replaced

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* RUCA

** University of Catania

by stainless steel electrodes. Facilities for tests, such as a stainless-steel container and a sample changer have been constructed.

A gas mixture of 95% helium and 5% nitrogen seems to be promising in view of the very high discrimination α-particles-fission fragments required for the ^{241}Am fission cross-section measurements. However, it is intended to make a more systematic study to find an optimum gas mixture.

6.2. Van de Graaff Accelerator

Operation of the 3.7 MV Van de Graaff Accelerator

A. Grametz, P. Falque, J. Leonard, R. Smets

Due to the installation of the upgraded accelerator tube at the end of 1973, the Van de Graaff accelerator can now be used up to 3.75 MW instead of the previous limit of 3.1 MV.

Out of 2812 working hours in 1974, 1810 hours were used for neutron physics experiments (including 165 hours for outside laboratories) and 272 hours were needed to condition the machine.
Several breakdowns occurred which required 609 hours of maintenance mainly due to vacuum leaks, high voltage leaks through the insulated piece around the corona and high frequency leaks in the post acceleration deflection box.
Because of tritium decontamination and of construction work at the present Van de Graaff building the accelerator has not been operated for experiments for 121 hours in the last six weeks of 1974.

Three ion sources built at CBNM were used during this year with an average life time of 600 hours.

In 1974 the ion energy scale of the accelerator has been calibrated twice, once in February and once in August. For the first time the threshold of the ^{7}Li(p, n) reaction induced by H_2^+ ions was used and the obtained calibration constant agreed within 0.1% with the mean value determined by other reactions at energies lower than 3.1 MeV.

To prevent the spread of tritium contamination (see section 10.1.) a special device for transportation of targets to and from the beam extensions was made.

The main outside user of the accelerator with a total use of 141 hours was the JRC-Petten in connection with a programme to study irradiation effects in structural materials. The main equipment was made in Petten, but vacuum tests and laser alignment were performed at Geel. In total, 238 vanadium samples had to be carefully adjusted for the irradiation with 2.8 MeV α-particles.

In January, 1974, 24 beam hours were used by the Radiobiological Institute TNO, Rijswijk, to compare neutron doses measured with a tissue equivalent ionisation chamber with the neutron KERMAs calculated from the neutron fluences and measured by CBNM instruments.

Modernisation of the Van de Graaff Accelerator

A. Crametz, P. Falque, J. Leonard, R. Smets

During the first six months of 1974 the technical and administrative aspects of the modernisation of the Van de Graaff accelerator were studied and the order for the purchase of a Elystron-fuelled Van de Graaff accelerator model CN with an upgraded tube was placed to HVEC in June, 1974.
The characteristics of the CN (7 MV) machine are given in Table 6.4.

Table 6.4.

D.C. Proton Beam Performance:

Energy	Proton Current
1.0 MeV	20 μA
5.0 MeV	35 μA
7.0 MeV	20 μA

Pulsed Proton Beam Performance:

Energy	Average Current	Pulse Width (FWHM)
1.0 MeV	3.0 μA	2.5 ns
2.0 MeV	4.5 μA	1.8 ns
3.0 MeV	6.0 μA	1.5 ns
7.0 MeV	6.0 μA	1.25 ns

The arrival of the equipment is planned for December, 1975, and acceptance tests will be made six to seven months later.
The beam lines connections from the exit of the analyzing magnet up to the two targets located on 0° and 45° exit ports of the switching magnet were studied during the non operating hours of the accelerator.

Development of a Convenient and Reliable Neutron-Gamma Discrimination Method for Proton Recoil Proportional Counters

A. Paulsen, F. Arnotte

A different rise time is observed for recoil proton-induced and electron-induced pulses in proportional counters due to the different average track lengths and their radial projections.
Two different methods have been tried: the 'rise time' method and the 'dividing' method (M. ÖBU et al., Nucl. Instr. Meth. [illegible]).

The rise time method has been tested at 50, 100 and 200 keV [illegible] has been shown that the counting loss of the proton recoil [illegible] spectrum gating is negligible. The dividing method is [illegible] under study. Unfortunately it is doubtful if these techniques [illegible] the range of applicability of proton recoil counting to lower [illegible] energies in Van de Graaff applications.

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European Institute for Transuranium Elements
EURATOM - Karlsruhe (Germany)

Fast fission yields and α-values of some nuclides

(G. Cottone, A. Cricchio, L. Koch, W. Krause[+])

Fission yields of Sb-125, Nd, Cs and Xe-isotopes were obtained for Np-237, U-235, Pu-239, Pu-24o, Pu-241 from capsules irradiated in the Rapsodie reactor (1). Isotope dilution mass spectrometry together with γ-spectrometry were used. For the evaluation of fission yields the usual normalisation procedure was applied (2) (table 1). α-values, which may characterize the neutron energy spectrum (3), were determined (table 2).

The relative fission yields of Nd-isotopes agree with earlier results (4) (table 3). The absolute yields, although they are systematically lower than those reported by (4) are still within experimental errors. An improvement in the given accuracies can be expected to result from the analyses of additional capsules.

+ Delegate of IRCH, Gesellschaft für Kernforschung, Karlsruhe

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Nuclide	Np-237	U-235	Pu-239	Pu-240	Pu-241
Sb-125	0.158 ± 0.008	0.064 ± 0.002	0.192 ± 0.005	[illegible] ± 0.006	0.121 ± 0.005
Xe-131	3.25 ± 0.16	3.17 ± 0.10	4.04 ± 0.12	3.43 ± 0.14	3.44 ± 0.14
Xe-132	4.86 ± 0.24	4.67 ± 0.14	5.46 ± 0.16	5.02 ± 0.20	4.69 ± 0.19
Cs-133	6.10 ± 0.31	6.85 ± 0.21	6.96 ± 0.21	5.88 ± 0.24	6.53 ± 0.26
Xe-134	6.96 ± 0.35	7.55 ± 0.23	7.33 ± 0.22	6.75 ± 0.27	7.23 ± 0.29
Cs-135	6.44 ± 0.32	6.66 ± 0.20	7.61 ± 0.23	7.00 ± 0.28	7.02 ± 0.28
Xe-136	6.59 ± 0.33	6.13 ± 0.18	6.63 ± 0.20	7.11 ± 0.28	6.64 ± 0.27
Nd-143	5.04 ± 0.25	5.64 ± 0.17	4.25 ± 0.13	4.59 ± 0.18	4.66 ± 0.19
Nd-144	4.46 ± 0.22	5.08 ± 0.15	3.59 ± 0.11	4.06 ± 0.16	4.08 ± 0.16
Nd-145	3.70 ± 0.18	3.69 ± 0.11	3.04 ± 0.09	3.21 ± 0.13	3.24 ± 0.13
Nd-146	2.98 ± 0.15	2.88 ± 0.09	2.50 ± 0.07	2.69 ± 0.11	2.92 ± 0.12
Nd-148	1.84 ± 0.09	1.66 ± 0.05	1.60 ± 0.05	1.86 ± 0.07	1.92 ± 0.08
Nd-150	1.04 ± 0.05	0.672 ± 0.020	0.991 ± 0.030	1.12 ± 0.04	1.23 ± 0.05

TABLE II

α-values of several fissile nuclides

nuclide	α-value
Np-237	1.05 + 0.05
U-235	0.213 + 0.007
Pu-239	0.134 + 0.003
Pu-240	0.300 + 0.007
Pu-241	0.111 + 0.003

Nuclide	Nd-143/148		Sm-149/1[illegible]		[illegible]		[illegible]	
	(4)	r.w.	(4)	r.w.	(4)	r.w.	[illegible]	r.w.
U-235	3.37	3.40	2.24	[illegible]	1.74	1.75	[illegible]	0.412
Pu-239	2.62	2.60	1.80	1.81	1.49	1.50	[illegible]	0.596
Pu-240	2.48	2.47	1.72	1.73	1.45	1.44	[illegible]	0.605
Pu-241	2.39	2.42	1.70	1.69	1.43	1.51	0.631	0.639